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NOVEMBER 2006

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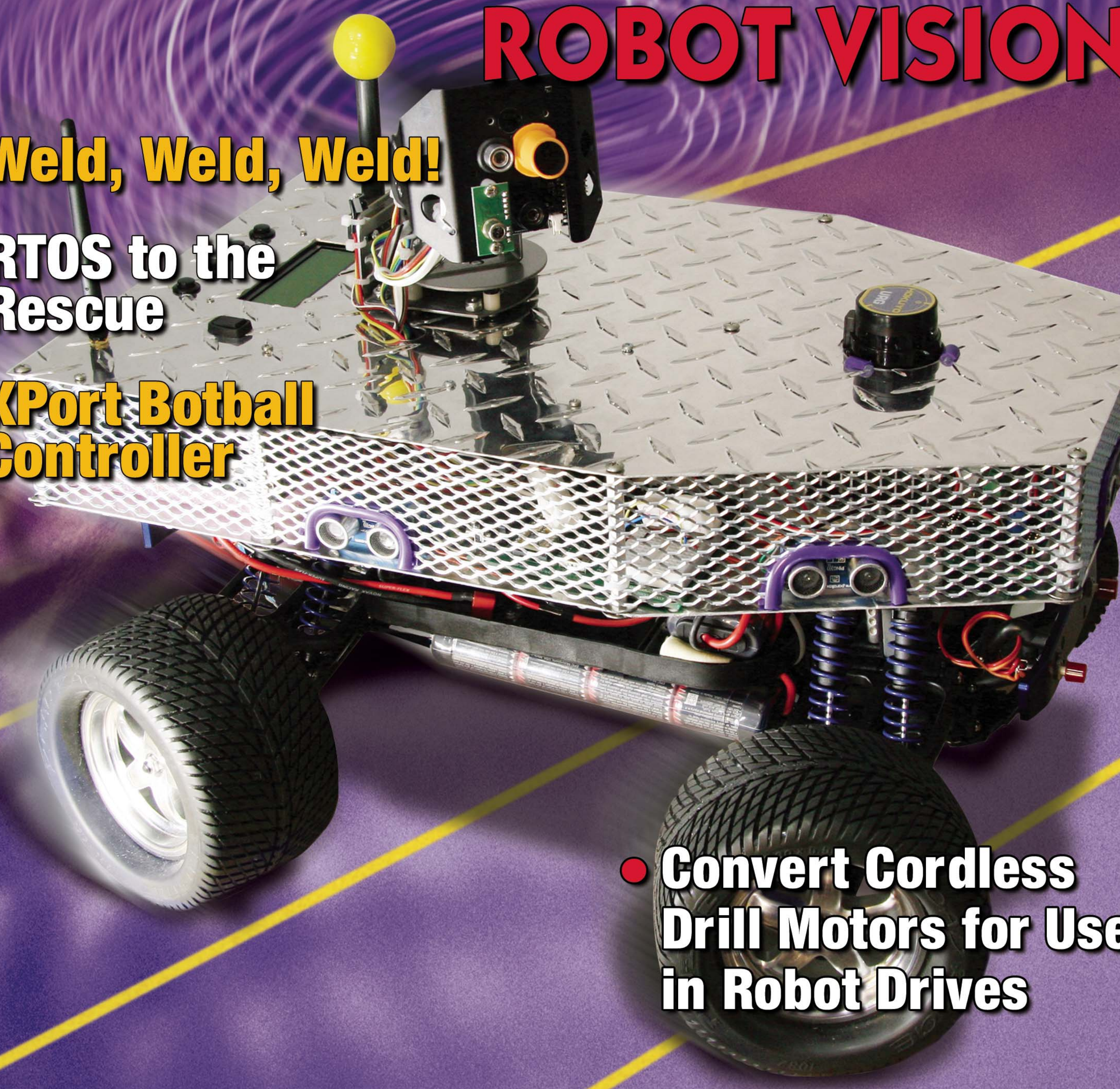

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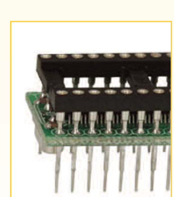

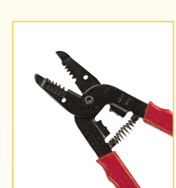

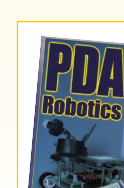

SERVO MAGAZINE

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SERVO Magazine **(ISSN 1546-0592/CDN Pub Agree#40702530)** is published monthly for $24.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL ENTRY MAILING OFFICES. POSTMASTER: Send address changes to **SERVO Magazine, P.O. Box 15277, North Hollywood, CA 91615** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@servomagazine.com

11.2006
VOL. 4 NO. 11

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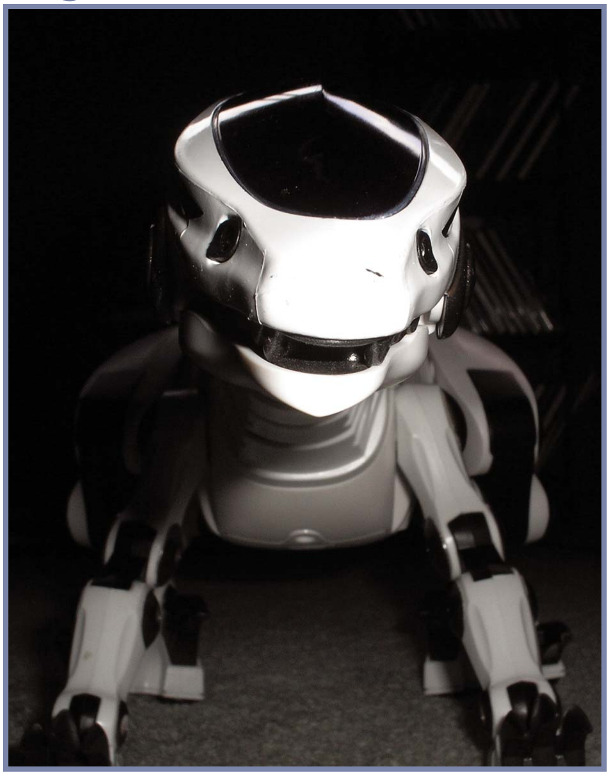

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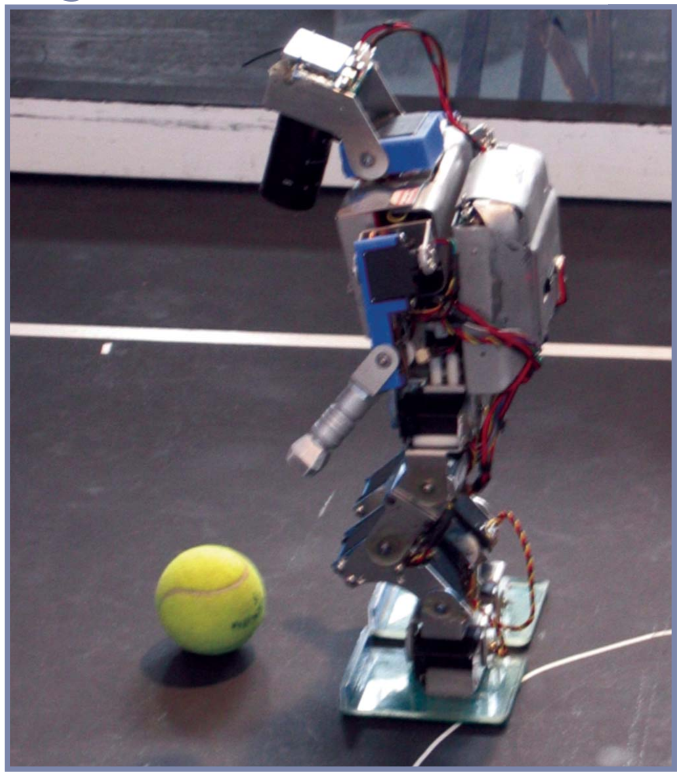

Features & Projects

Mind / Iron

by Evan Woolley

Donning the Mentor Hat

Mentoring is an important aspect of the field of robotics. Robotics can be an intimidating field, especially to young students considering study and a career in science and technology. Having the guidance of a mentor can really be the deciding factor that gives a student the confidence and inspiration that they need to make the choice to become an engineer. I know personally that my mentors have meant a lot to me, so I jumped at the chance to help others in that same way.

After spending three years on a FIRST robotics team, it seemed like the natural next step to return in subsequent years as a college mentor. And it seemed easy enough to step into the role of "mentor" — I just tried to emulate what my mentors had done for me. And after donning the mentor hat, I really realized that giving encouragement and dispelling doubt were as much of the process of mentoring as technical instruction. I also discovered that helping someone else bring their idea to fruition was just as rewarding as seeing my own come to life.

It's kind of funny. While I was actually on my high school's FIRST team, I don't think that I ever formulated a really good idea of how creative everyone else on the team was. I was focused more on my own ideas, and though I tried to be receptive to what the others had to say, I still think I was a bit biased toward my own ideas, and I think that is a natural tendency. When I witnessed our robot perform well in competition, I naturally focused on the aspects of the design I worked on, and as a result I attributed success in a match to the area of my focus. As a mentor, I was detached enough from the initial design process so that I was really able to appreciate how creative everyone else really was, and I was really able to appreciate the contributions that everyone made to the project. I find this funny because it was only after leaving the team that I realized how important the team as a whole was. I think my appreciation of the effectiveness of the team was really one of the main benefits I derived as a mentor.

And I think this appreciation and awareness led me to seek out more opportunities to mentor, and it just seemed like another natural progression. Many of the students on my high school FIRST team were also members of the solar boat race team. I had never really been involved on the team during my high school years (too busy with robots), but I found myself involved as a mentor. Of course, I did learn a few more things about solar power than I did before, but what really drew me in was not only the thrill of achieving a goal, but the thrill of helping others achieve something. That might sound like a wallflower's vicarious thrill, but it's quite the contrary. Whenever I was on a robot team, it really felt great to do well in competition. What I usually focused on, though, was how my contribution was a part of the victory. Again, I think this is natural, albeit a bit selfish. As a mentor, I found myself really able to appreciate the victory of the team — it was a selfless thrill. Selfless in that I was able to really appreciate how everyone had a hand in the victory. Not only

Mind/Iron Continued

Published Monthly By
T & L Publications, Inc.
430 Princeland Court
Corona, CA 92879-1300
(951) 371-8497
FAX **(951) 371-3052**
Product Order Line **1-800-783-4624**
www.servomagazine.com

Subscriptions
Inside US **1-877-525-2539**
Outside US **1-818-487-4545**
P.O. Box 15277
North Hollywood, CA 91615

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BIO-FEEDBACK

Dear SERVO:

Wood — it's what my robots are made of. It's snubbed by most builders of robots. So I was pleased to see Robotics Resources recommend it. However, I am a little disappointed that McComb did not place more emphasis on gluing. The ease of making strong glue joints is an important advantage that wood has over metal and most plastics. Well-designed glue joints are the key to high strength to weight wood structures. Wood airplanes — and that includes some World War II fighters — are glued together.

By the way, ANC — 18 bulletin, *Design of Wood Aircraft Structures*, June 1951, contains a lot of information useful to builders of wood robots. Unfortunately, I have no idea where you can get a copy.

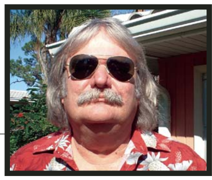
Also, I would like to point out that thin (1/64" to 1/2") birch plywood is available mail-order at about half the hobby shop price. One such source is: Lone Star Models, **www.lonestar-models.com**

William J. Kuhnle
Lavon, TX

could I experience my enjoyment, but the whole team's enjoyment.

But, of course, a mentor gets a lot more out of the experience than the vicarious enjoyment of other people's projects. You hear it all the time, but the mentored give just as much back to the mentor. It might not necessarily be in technical knowledge (though high school students can surely have surprising insights), but they certainly return inspiration twofold. When you realize that you've given at least one person confidence, that is a huge thing. It goes beyond the victory in a single competition. It encompasses academic victories and professional victories and personal victories, because you've helped steer someone on a path that they will find exciting and rewarding.

Of course, my model of transition from team member to team mentor wouldn't work for everyone. Many of the mentors in organizations like FIRST didn't have the benefit of being on the team first, and many possible mentors out there in the world didn't either. The good news is that it is very easy to become a mentor, especially in the fields of science and engineering. FIRST teams are everywhere nowadays, as are LEGO League teams, BEST teams, and now there are emerging Vex Challenge teams. There are groups everywhere in need of mentors. The only requirement is the will to inspire and to be inspired. SV



Robytes

by Jeff Eckert

Are you an avid Internet surfer who came across something cool that we all need to see? Are you on an interesting R&D group and want to share what you're developing? Then send me an email! To submit related press releases and news items, please visit www.jkeckert.com

— Jeff Eckert

Military UAV Achieves Autonomy

Boeing's PMTD UAV during a test flight. Photo by Peter George, courtesy of Boeing.

In a recent test flight from the Vandalia Municipal Airport in Illinois, Boeing's (**www.boeing.com**) Persistent Munition Technology Demonstrator (PMTD) flew autonomously for the first time, navigating to 14 programmed locations accurately, changing altitudes at four different points, and operating at various preplanned speeds. The 60-lb vehicle, with a wingspan of 12 feet, was created to demonstrate emerging technologies via incremental upgrades and various demonstration phases and to serve as a test bed for future small UAVs. It is designed for extended loiter times and can be air or surface launched.

In the test, the PMTD took off and landed under remote control, but the flight itself was conducted without any human intervention. Having completed this first phase of development, the company's future plans include sensor integration and a demonstration of weapon terminal guidance, as well as possible in-flight refueling and munitions dispense testing. The vehicle is the result of a joint effort by EDO Corporation (**www.edocorp.com**), which funded development of the composite airframe, and Boeing's Integrated Defense Systems division.

Consortium Looks at Civil UAVs

The ASTRAEA program is aimed at enabling common-place civil use of UAVs developed from current models such as the Herti 1A and the IAV2 vertical takeoff and landing (VTOL) vehicle. Photos courtesy of BAE Systems.

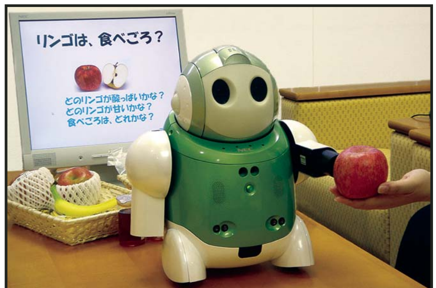
Most of the focus of UAV development is aimed at military applications, but that may change in coming years. Britain's Autonomous Systems Technology Related Airborne Evaluation and Assessment (ASTRAEA) program (**www.astraeaproject.com**) is a £32 million (~$60 million) effort to open up opportunities for routine civil use of UAVs in segregated and nonsegregated airspace for such purposes as environmental monitoring and security.

Projects encompass key technologies and considerations including collision avoidance systems, communications, flight control, propulsion, autonomous decision making, health monitoring, and affordability. Whereas ASTRAEA specifically focuses on the technologies, systems, facilities, and procedures that will allow uninhabited vehicles to operate safely and routinely in the UK, it has obvious long-term implications elsewhere, and a stated goal is to position the UK as the world's leader in the technology by 2022.

The consortium includes such companies as BAE Systems, EADS, Agent Oriented Software, Flight Refuelling, QinetiQ, Rolls-Royce, and Thales UK, plus renowned research and academic bodies and other small and medium-sized enterprises. BAE Systems (which is Europe's largest defense company) already has considerable experience in the field (see photos).

Will the civilian skies soon be swarming with unmanned police planes? Will pizza be delivered by small autonomous dirigibles? Stay tuned.

Robot With Taste?



This robot, developed by NEC and Mie University, is billed as a partner robot with a sense of taste. Photo courtesy of NEC System Technologies.

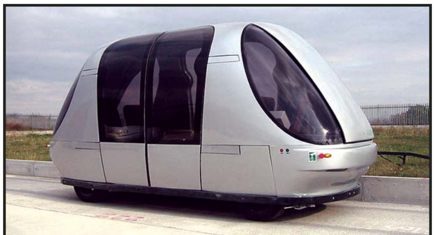
One interesting bot that may have escaped your attention is the food tasting robot developed by NEC System Technologies and Mie University, dubbed by some as the "winebot" because of its ability to identify different types of wine. However, in demonstrations, it has also successfully identified several types of cheese, meat products, and bread, often without even opening the package. You may have already noticed that the little guy doesn't have a mouth, which would seem to make tasting things difficult. And, in fact, it does not have a sense of taste in any normal meaning of the word.

What it actually does is employ an infrared spectrometer, mounted on its left arm, to analyze the food, providing

not only identification but also quantity estimates of components such as sugar and fat. Observers have noted that the technology still needs some refinement.

One reporter was identified by the robot as prosciutto, and another individual was deemed to be bacon. If the technology were adapted to a robotic chef, the results could be both tragic and unappetizing.

EU to Eliminate Drivers



A new EU project called CityMobil seeks to improve driving conditions using autonomous vehicles such as the "ULTra®," built by Britain's ATS Ltd. Photo courtesy of ATS.

If you have developed an aversion to the attitude and occasional aroma of taxi drivers, you will take heart at a recently announced project sponsored by the European Union (EU). The CityMobil concept — which has been funded to the tune of 40 million Euros and involves 28 partners in 10 countries — is aimed at replacing human drivers with autonomous vehicles wherever feasible. In fact, one of three trial sites is London's Heathrow airport. (The others are the town of Castellón, Spain, and an exhibition center in Rome.) By 2008, Heathrow will incorporate a route that covers 4.2 km of track, including station loops, and 18 of the ULTra Personal Rapid Transit (PRT) vehicles provided by ATS Ltd. (**www.atsltd.co.uk**).

The "rapid" part is a relative term, as it has a maximum speed on level ground of 11 m/s (24.6 mph), which isn't bad for buzzing around the airport. A typical one-mile journey will take approximately three minutes. The battery-powered 3.7 meter long vehicle will carry up to four people, assuming their total weight doesn't exceed 500 kg (~1,100 lb), and heat and air conditioning can be provided where required.

All of this sounds like a modest start, but CityMobil envisages much larger driverless public transport systems that take you virtually anywhere you want to go. For more details, visit **www.citymobil-project.eu**.

Snakebot to Fight Fires

SINTEF's Snakefighter project has resulted in a hydraulic snakebot designed to fight fires and dispense various liquids. Photo courtesy of SINTEF.

If you have ever seen a garden hose moving around on its own, the concept should have been obvious. But it took until 2003 for a research scientist at Norway's SINTEF Group to think of building a self-propelled fire hose that can enter a burning building on its own and put out the fire without risking human life. Hence the Snakefighter project.

This year, it bore fruit in the form of (someone just couldn't resist) "Anna Konda," a 3 meter, 70 kg snakebot that uses hydraulic valves and actuators to slither like a snake. The bot cleverly taps into 100-bar water pressure that already exists in the attached fire hose, and that provides it with enough power to raise its head and aim the spray, climb stairs, lift heavy objects, and even break through a wall.

Other potential applications include subsea maintenance of oil and gas installations — anything that requires snake-like action. (Well, not *anything*.) The company is looking for collaborative partners to help with continuing development of the system, so if you are interested, stop by their website. The English version is at **www.sintef.no/default____490.aspx** (that's a quadruple underline). **SV**

GEERHEAD

by David Geer

Contact the author at geercom@alltel.net

Battery Operated Smart Servants Know You're the BOSS!

Robotic Assistance is in the Basket

Humble Beginnings; Hey, Add a Motor to Me, Will You?

Starting from a "standard, small frame" shopping cart, the Battery Operated Smart Servant (BOSS) creator Greg Garcia — graduate research assistant in the center for intelligent machines and robotics, the University of Florida — modified the future BOSS robot's wheels and chassis by removing the default wheels using a "4.5 inch angle grinder with cutoff wheel."

Then, on a newly fabricated L bracket, Garcia mounted the robot-to-be's motors, having traced out and drilled bolt holes in a pattern matching the holes in the motors' base. He also drilled a clearance hole for the motor shaft to traverse. The remaining, opposite surface of the L bracket was left untouched for easy welding to the cart.

BOSS employs Denso 12-volt DC motors. These geared, right angle DC motors produce greater torque, suitable for those 'high-test' applications. "The worm gear [used in these motors] translates the rotational effort of the motor about an axis perpendicular to the motor; this keeps the motors in profile along the vehicle," says Garcia.

These motors can turn at 150 revolutions per minute. Together with the eight-inch tires that Garcia specified, this enables BOSS to move fast enough to keep up with most people.

The motors are powered by a series of four 12-volt batteries wired in parallel in order to form one larger 12-volt battery (to wire them in parallel, all the negative terminals are connected each one to the next, and likewise with the positive terminals).

Keeping the BOSS Under Control

The motors are controlled by an H-bridge motor controller — the Tecel model D200 — which is compatible with motors requiring up to 60 amps of current. The controller also uses four 110 amp MOSFETs (metal-oxide semiconductor field-effect transistor).

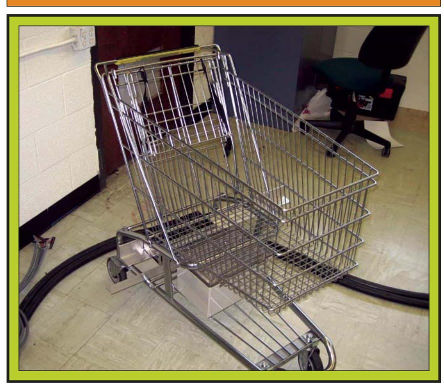
The controller blocks, allows, and directs current using gates or switches in order to switch the motors on and off and to guide the motor's rotation directions. You control the H-bridge by sending pulse width modulated signals that set the motor duty cycles (speed); motor direction is set by sending digital signals that express the selected direction that the motors — and ultimately BOSS — should travel.

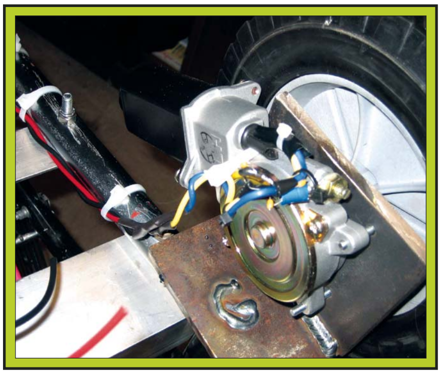
The primary data in/out for BOSS is controlled by a MAVRIC IIB microcontroller board. The board employs an

BOSS at the beginning — just a simple shopping cart.

This is BOSS' preliminary structural design for placement of the battery.

Deciding where to put the electronics enclosure.





Drive motors with noise reduction circuitry.

At this stage, BOSS' battery is mounted and secured.

The battery secured.

Atmega128 MCU (microcontroller unit). The MAVRIC was chosen for its versatility when applied to multiple sensors and input and output data. An analog-to-digital converter converts analog data from three infrared distance-measuring sensors to a digital signal the controller can understand.

Digital I/O also delivers signals between the sonar sensor and the warning buzzer. The signals traverse a coil relay to turn the buzzer on; I/O also sends data to the LCD. RS232 serial connections are used so that the microcontroller can talk to the image-processing computer.

The microcontroller programming can be coded using a variety of programming languages. "I used a software package called CodeVision, which consists of a number of C libraries that contain function calls designed to interface with the ATmega128. The programming of the vision algorithm was also done using the C programming language. It was accomplished using Microsoft Visual Studio 6 and Intel's OpenCV (open source computer vision) libraries," says Garcia.

The BOSS Can See You

The BOSS' vision program pulls video input from a Logitech USB quick cam. Garcia used his own image processing algorithm runs in order to create the proper reactive control action and send it to the microcontroller. "This level of processor computation is too great for the microcontroller to handle, so it is outsourced to a higher power computer. This vision functionality is a very primitive solution to a complicated problem," says Garcia.

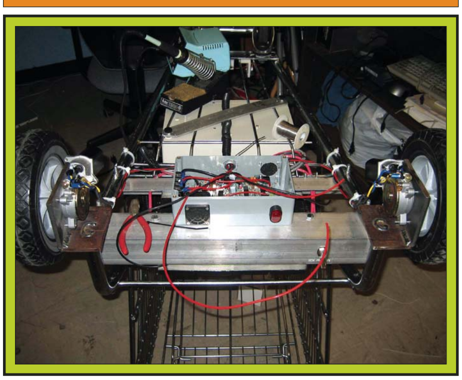
BOSS uses its vision facility to track objects based on color recognition. By adding other functionalities, Garcia was able to make this simple tracking modality much more robust. Extraneous factors like lighting and shadowing affect the quality of color recognition that can be performed. To offset this, Garcia gave BOSS a training function and built tolerances into his algorithm, to allow for variances after the training

LESSONS LEARNED ABOUT CABLING

During the creation of BOSS, Garcia learned that noise has a highly detrimental effect on sensor information. He also learned how to avoid it:

- Use good shield wiring.
- Run power lines separate from data lines whenever possible.
- Mitigate noise from DC motors. "There are many simple ways to filter out this noise using a combination of capacitors and resistors. For example, on my drive motors I used some 10 microfarad ceramic capacitors to reduce the noise output. One capacitor was bridged across the positive and negative voltage leads, while two more were ran from the positive lead to the motor case ground and the negative lead to the same motor case ground," says Garcia.

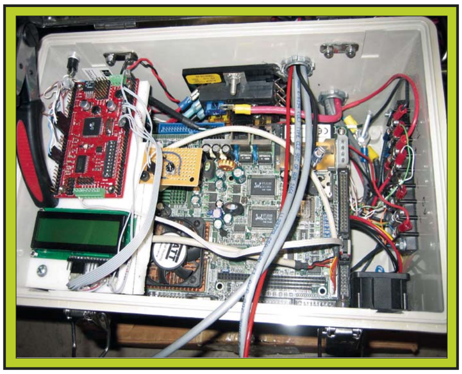
Motor controller housing unit.



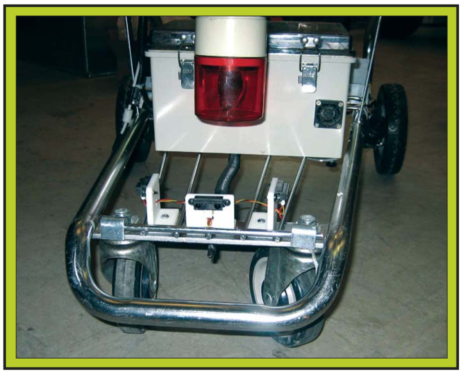
BOSS with battery kill switch.

BOSS side view, early stages.

Here the warning light has been mounted.



BOSS computer brains, open and ready for inspection.



BOSS front view; IR sensors have been mounted.

phase of color-based object recognition.

When the vision program begins, a prompt asks the user to select the color she/he is wearing from a list of available colors. The user must then obscure the camera's view with what they are wearing. "This allows the computer to know its color under the given lighting conditions," says Garcia. Tolerances are built into the Red-Blue-Green color values to mitigate minor lighting changes. If BOSS can't gather enough color information based on the image for the algorithm to make a decision, the robot will stop and sound its buzzer to let the user know there is a problem.

BROADER LESSONS LEARNED

"Nothing is as it seems," says Garcia, to borrow an old adage. Greg learned that actions and motions like pushing a shopping cart or following someone become very difficult when you try to reproduce them in machines alone. It requires "incredible" computer power and sensing. These behaviors are easy for us because we recognize not only color but also shape and other characteristics. "We don't have to pull out a tape measure and check each doorway, we glance at it and know whether we can pass or not. We can also step over small boxes which a wheeled robot cannot do," says Garcia.

Makes Sense to Follow Along

More than a shopping cart with a brain and sensors, BOSS homes in on its master's image to follow and deliver its cargo.

BOSS uses both IR and sonar ranging sensors for positioning. In this way, BOSS can know its relative distance from objects in it environment and know its own positioning. The sonar itself is specifically for ranging the distance between BOSS and its master.

"This sensor is mounted inline with the camera so it measures the distance to whatever the camera is pointing at. This sensor controls the cart's following behavior. If the cart is too far away from the target, it will speed up. Conversely, if it is too close it will slow down or stop. But, it will stop close enough to you to not hit you and yet allow you to put things in the cart," says Garcia.

The sonar is a Devantech SRF 05 ranger. It works by transmitting ultrasonic pulses. It counts the time between sending the pulse and hearing its echo to determine distance, as sonars generally do. The sonar's pulse can't be detected by the human ear. This particular sonar has a range of up to four meters.

The IR sensors are Sharp GPD 12s. These are mounted close to the ground. The mounting allows BOSS to see in front of itself and to each side. These sensors locate minor obstacles in BOSS' path. They are limited in range, which is sufficient for their task. These sensors can sense up to 30 centimeters.

"When an obstacle is detected, the cart will stop and sound an audible tone alerting the user that the path is blocked. These sensors are currently used to prevent the cart from having a collision. Based on empirical tests, it has been shown that if the user follows a clear path, that the cart too will follow said path," says Garcia.

A rear view of BOSS' electronics enclosure.

This is BOSS' motor actuation box.

Why, BOSS?

Garcia is most frequently asked why he built BOSS and how he got the idea. It was mostly to satisfy a class requirement (EEL 5666c Intelligent Machines Design Laboratory). The freedom to design and create what he wanted — within the class requirements — was a factor in his enthusiasm for the job.

At this stage of the build, the warning light has been repositioned.

BOSS GETS AROUND

No, the BOSS wasn't invited to join the Beach Boys, but it does "get around" in a really cool way. The BOSS uses skid steering to move and groove. This means that two front caster wheels and two rear multidirectional orientation wheels are employed. By telling the rear wheels to spin at varying speeds or opposite directions, BOSS can make zero turn radius turns, according to Garcia. BOSS doesn't do reverse yet, as there are no sensors in the rear to guide it.

"I believe that robots should be used primarily to save human lives where at all possible. But, if that is not an option, they should at least be able to enhance our quality of living," says Garcia. It was the latter motivation that lead Garcia to come up with plans for BOSS. People can easily get caught up in the drudgery of every day chores and tasks, for example, when Garcia had to go along to the grocery store as a kid.

"You see, I have an older sister. We always wanted something to do in the store while we were with our mother so we would ask to push the cart. I guess she really didn't like doing it because she would always agree. Anyway, my sister would somehow always find a way to "accidentally" bump into me. So I started thinking of how to avoid this," explains Garcia.

The more Garcia pondered the problem and those memories, the more he remembered the nuisances of using a shopping cart. Sometimes people forget where they've left their carts. Then, they have to go back and get them. That's how Garcia arrived at the solution he calls BOSS.

NOVA 7896 SBC with CIMAR PS, MAVRIC IIB, and LCD all mounted and powered in box.

Beyond this, Garcia sees the possibility that a smart servant could help the disabled. "The same day the AP story broke about our robots, I got an email from a woman who is disabled. She has limited use of one arm and suffers intense pain when having to single-handedly push a shopping cart. She requested that I keep her up to date on the development of this technology," adds Garcia.

Conclusion

Garcia simply added eyes, brains, and mobility to a shopping cart. And, yet, it's clearly one more step toward the close proximity we will all share one day with the many servant and co-worker robots to come! **SV**

RESOURCES

The BOSS at home on its Web-based crib
http://grove.ufl.edu/~garcia/

BOSS in action. Catch the video here:
http://grove.ufl.edu/~garcia/BOSS_internet.wmv

Tecel motor driver board
www.tecel.com/d200

MAVRIC controller board
www.bdmicro.com/mavric-iib

Logitech
www.logitech.com

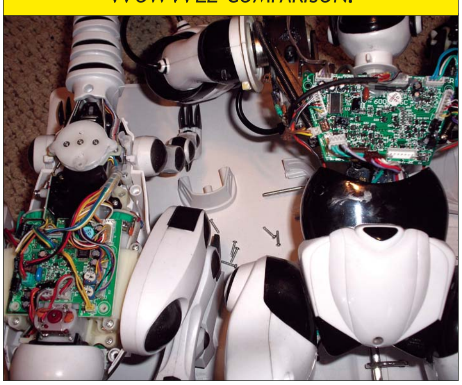
Devantech
www.robot-electronics.co.uk/a

This month, we have the pleasure of presenting the newest addition to the WowWee Toys robotics family — the Roboreptile. The Roboreptile is the new version of the Roboraptor, and this new generation is sleeker, faster, and even more precocious, if that is at all possible. The only other member of the WowWee family that we've had major experience with is the classic Robosapien and, given the Robosapien's reputation for expandability and experimentation, we had high hopes for the Roboreptile. Will this new lizard on the block be the king of the dinosaurs, or will it be at the bottom of the food chain? There was a quick way to find out ...

King of the Dinosaurs

But before an epic showdown, we needed to know what the Roboreptile was capable of. The Roboreptile — like other WowWee products — is operable right out of the box after the procurement of a few AA batteries. The devilish dino is ready to play immediately — it comes with three preprogrammed behaviors. The first behavior the Roboreptile exhibits is the "feed" mode. While feeding, the Roboreptile will prowl around, reacting to its environment via sound and infrared sensors. The reptile will not calm down until it is "fed," which can be achieved by pressing the "feed" button on the remote.

WowWee comparison.



Remote addition.

When we first read about the feeding behavior, we were a bit curious about what was meant when it was said that the reptile wouldn't calm down until fed. The Roboreptile comes with a hood that, when worn, will effectively tranquilize the robot dino by stopping it in its tracks. But if you try to put the dino's hood on before it has been fed, it will vehemently shake the hood off — if the Robosapien family boasts a fusion of technology and personality, then the Roboreptile is definitely the maladjusted teenager of the group. That's not to say that it isn't entertaining; quite the contrary.

We both loved to play with dinosaur toys when we were kids, and even with just the feeding mode the Roboreptile would have been the coolest toy ever. In addition to the basic feeding behavior, the Roboreptile can also simply "roam," using sensors to avoid obstacles, and "guard," where the dino crouches on its hind legs and waits until it is provoked, after which it will lunge at the offending sound or motion. In addition to the preprogrammed modes, the Roboreptile can be controlled via individual commands given by the infrared remote.

Besides the modes that come pre-

programmed, the Roboreptile exhibits several "moods." The feeding behavior is characteristic of the "hungry" mood. While hungry, the reptile is the most aggressive, even chasing after the remote control if the user taunts it with the feed button too much. Once fed via the button on the remote, the Roboreptile displays the "satisfied" mood, where it moves more slowly and is more amenable to being "hooded."

"Hooded" is the last mood, where the Roboreptile's sensors are inactive. If left hooded for long enough, the Roboreptile will eventually fall asleep and power down. The Roboreptile's moods certainly make it an interactive and entertaining toy, and there are many more positive traits it exhibits beyond personality.

The Roboreptile is advertised as much faster than its predecessor, and the feisty dino certainly makes good on this claim. The Roboreptile can scoot around at an impressive speed by using its stubby front arms as skids of sorts. The reptile's waving tail and swaying head really create a realistic motion as the creature prowls around, and the bot is hugely entertaining even in demo mode.

In addition to the fluid movements, the Roboreptile can create a variety of sounds, ranging from ragged breathing to beastly roaring — perfect for terrorizing housepets. Granted we've never seen real dinosaurs in action, but if we ever come across one, we're sure it would saunter around and sound a lot like the Roboreptile.

Beyond all of the mayhem the Roboreptile is capable of simply with its preprogrammed behaviors, the bot also has the ability to be programmed by the user. The user can enter a sequence of up to 20 moves through the remote. The Roboreptile comes with a veritable plethora of possible moves, including a "tail strike," "bite," "shake," and even one called "dizzy." Such variety means tons of possible 20 move sequences — definitely more than enough to keep even the most jaded dinosaur expert entertained for hours on end.

The Roboreptile certainly makes a good first impression with its overflowing personality and lifelike movements. The robotic dinosaur is unquestionably entertaining, but is that enough to make it the king of the dinosaurs?

KING OF THE DINOSAURS! GRRRRR!

Stomping Grounds

Argus is our German Shepherd dog. If the Roboreptile could hold its own against such a fearsome adversary, then surely its dominance would go unquestioned thereafter. Unfortunately, even the Roboreptile's fearsome lunges and roars stood no chance against Argus' jaws. What could be done to help the Roboreptile reassert its dominance? An early idea was to emulate the mythological dragons of yore and give the Roboreptile the ability to breath fire, but that project presented the risk of a melted plastic dinosaur if things went awry.

Everyone has heard of a fire-breathing dragon anyway, and we are never ones to fall back on tired clichés. We came up with the more constructive idea of making the Roboreptile breath smoke — carbon dioxide gas. This way, the Roboreptile could put out fires instead of start them. Such protective tendencies would certainly make a less Machiavellian king of dinosaurs, and the ability to put out fires would make the Roboreptile a great role model for kids if anything unfortunate should happen to Smoky the Bear.

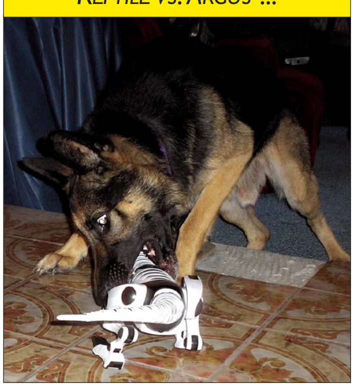
Back From Extinction

The first order of business that needed to be addressed was to become acquainted with the Roboreptile's insides. The Roboreptile has a much more compact board than its distant cousin, the Robosapien, though such is to be expected with the smaller lizard. As was the case with the Robosapien, all of the wires that connect to the board do so through sockets, and this feature makes it easy to flip over or remove.

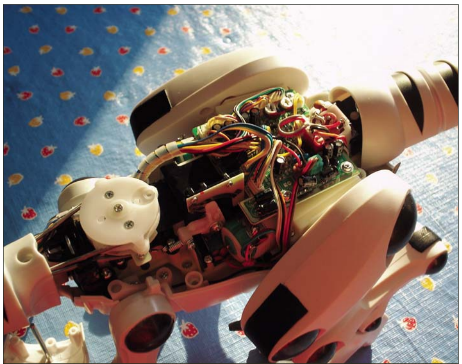
Removing the board is the only way to get a deeper look into the Roboreptile, and the backside of the PCB. An inspection of the PCB's backside reveals that all of the pins are conveniently labeled by their function — everything from leg and tail motor ports to test pads. A look at the mechanical workings of the dinosaur reveals that the Roboreptile abides by the same principles of reflexive motion as the Robosapien, so just by taking a look inside anyone can learn a thing or two about efficient engineering.

The Roboreptile uses very few servo motors to achieve its wide range

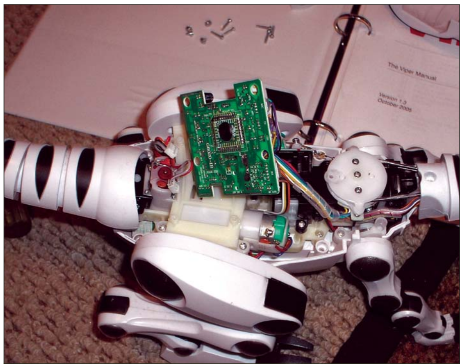
REPTILE VS. ARGUS ...



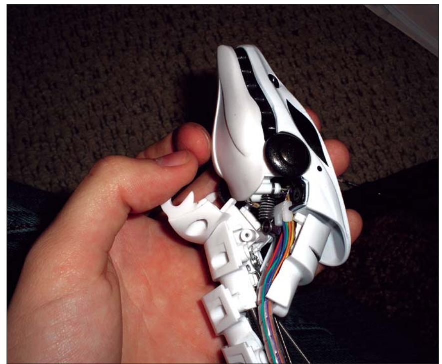
THE FIRE EXTINGUISHER.



CHECK OUT THE DINO GUTS!



EW, MORE INSIDES!



THE REPTILE SKULL.

of movements. A great example is the decidedly reptilian waving of the bot's tail. At first glance, the movement of the segmented tail seems to be a complicated motion — such graceful kinetics seem like they should be achieved by complicated mechanisms. But such is not the case — the tail mechanism is simply a single servo motor that moves the base of the tail back and forth. The ingeniously designed segments of the tail are made in such a way as to create a smooth motion with no further locomotion. Similar graceful minimalism is to be found throughout the entire robot.

In various ways, however, the Roboreptile is a lot less intuitive for hackers than its humanoid progenitor. One glaring example of this literally glares at you — the head of the Roboreptile, with those beady little eyes, is a lot more difficult to get into than the Robosapien's dome. First of all, the Roboreptile's head cannot be accessed until all of the neck segments have been removed. This should have been a clue, because once we finally worked our way to the head, we discovered that the dino's skull was not meant to be breached.

After dismantling all of the neck segments, the only dismantling that can be done to the head is the removal of a small part at the base of the skull — the jaws cannot even be split apart. So, it is our recommendation that the only way one should attempt to get inside the head of the Roboreptile is through a series of clever mind games.

Feeding the Roboreptile

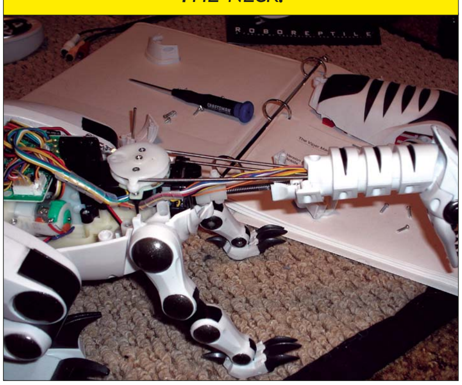
Just because the Roboreptile is resistant to major surgery, that doesn't mean we can't get started on its firefighting modification. Our initial vision was to give the dino the ability to spew compressed CO_2, perhaps even through a tube snaking through the bot's neck. Our idea was that if the tube had a small enough opening, the expelled gas would look like a puff of smoke.

Normal-sized pneumatic parts were too big to turn the Roboreptile into a small fire extinguisher, so we had to find something a little more scaled down. As it turns out, the Roboreptile is of similar proportions to a paintball gun. The tiny CO_2 cylinders used for paintball guns would be a perfect fit for the robotic dinosaur, and we could scavenge the valve from a paintball gun to ensure a controllable release of the gas. So we bought a paintball gun, after which we did what we think should be done to all paintball guns — we dismantled it so the parts could be used in far more useful applications. In this case, that application would be a fire extinguishing dinosaur.

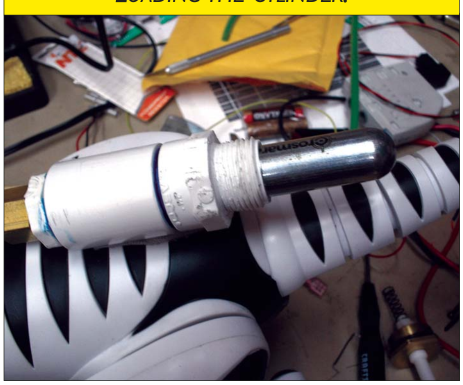
After dismantling the paintball gun, we discovered that the mechanism we needed was housed in a large and unwieldy casing. All we wanted was the portion that punctured the cylinder seal, so we cautiously dissected the spring loaded casing. Much to our pleasant surprise, the desired piece could easily be unscrewed from the open casing. Unfortunately, by taking only the part we wanted from the paintball gun, we lost the ability to hold the cylinder in place. Fortunately, the tiny cylinders happened to fit perfectly into some PVC pipe, and a screw-on cap provided the perfect method to press the cylinder onto the pin.

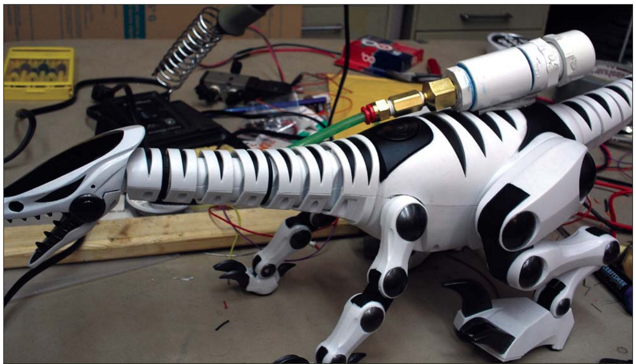
The other element we needed for our smoke-breathing Roboreptile was a way to control our hacked addition. We had some leftover pneumatic solenoids from FIRST robot kits, and we also scavenged a remote radio control to turn our mechanism on and off. We are sure clever hackers could devise a way to operate additional mechanisms via the original remote, but we wanted to do things as easily as possible.

THE NECK.

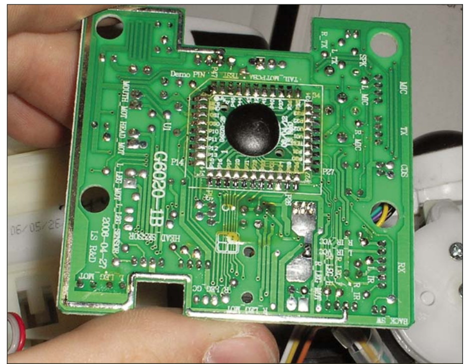


LOADING THE CYLINDER.





THE REPTILE AND THE TANK.



THE REPTILE PCB.

Our plan to give the Roboreptile smoky breath was to bodge together a mechanism that would consist of the PVC pipe to hold a CO_2 cylinder, connected via a tube to a pneumatic solenoid that could regulate the exhaust. The solenoid could ideally be powered by the existing power supply of the Roboreptile, which is also how we planned to power the receiver for our radio control. All that was left would be one last tube connecting to the solenoid. It sounds simple enough in concept, but convincing the Roboreptile to adopt its extra equipment proved to be rather difficult.

Stratigraphic Shenanigans

In our attempts to hack pneumatic solenoids onto the Roboreptile's PCB, we came across several difficulties that indicate the bot should only act as an expandable platform for serious tinkerers with a bit of an electronics background. The Roboreptile has a PCB similar to the sedimentary layers that buried its prehistoric ancestors — in other words, a multi-layer PCB.

The Roboreptile operates on six AA batteries — nine volts. The pneumatic solenoids at our disposal were intended for a 12 volt system, as was the radio control. We did test the solenoids and the radio control at nine volts and both of the devices actually worked. It looked like we were in the clear, but our initial test of the solenoids was not done under pressure. When we tested the solenoids under pressure using an air compressor, we discovered that nine volts would not provide the requisite power. We thought an easy solution would be to add two more AA batteries in series to give us the last three volts we needed. We could also use some diodes in the circuit to ensure that the rest of the dino's electronics would remain unaffected by our thirst for power.

But the multi-layered PCB apparently splits the voltage between the layers — three volts for one layer and six for the other. Because of the voltage schism, we couldn't easily attach two more batteries. We tried to find the nine volts coming directly from the battery pack before the split, but even after a thorough investigation of the PCB with a multimeter, the nine volt source eluded us. Were that somewhere in the depths of the Roboreptile's innards there existed a nine volt source, but we were unwilling to dissect the bot that extensively.

The Roboreptile is so compact in its assembly that any major dissection would involve the excavation of layers and layers of casings and mechanical bits. In this sense, the Roboreptile is rather unfriendly to hackers. Were that there are plenty of bits that determined hackers could badge on that would only need six volts, but the limitation is certainly disheartening. Another caveat deserves to be mentioned here — the Roboretile's rambunctious nature drains the batteries at an alarming rate, and after a few hours, the dino will begin to slow down. Any hacked additions would add even more of a power demand on the reptile's batteries, so hackers beware. But even at full power, with a maximum of six volts at our disposal, it looked like our dreams of a solenoid controlled fire extinguisher were going up in smoke.

Smoke and Mirrors

We were in a bit of a hard place with the Roboreptile. Our solenoids and our receiver all depended on 12 volts, but the most we could squeeze out of the dinosaur was six volts. And even if we could wire all that to the bot, its compact design would force us to attach everything to the outside of the dino. The prospect of bodging a solenoid, radio receiver, and extra batteries onto the shell of the Roboreptile was not a very intuitive solution. But we were determined to make the Roboreptile breath smoke, so we began to consider a more mechanical solution.

The minimum that we would need to make the dinosaur breath smoke would be our custom PVC pipe, a CO_2 cylinder, and a short length of pneumatic tubing. The mechanism would be purely mechanical in this sense, because all that would be required for activation would be to screw on the end cap that would puncture the cylinder seal on the pin. Then, all of the gas would be exhausted at once, but we were pretty confident that would create the effect we were hoping for.

After being frustrated by the unfriendliness of the Roboreptile's electronics, we were certainly ready to try the mechanical solution. After attaching the firefighting apparatus to the dinosaur's back, we were ready to test. Our first test was, well, quick. Once the cylinder was punctured, the $C0_2$ did indeed whoosh out in an instant, even creating a visible cloud. The problem was that the mechanical nature of the execution did not lend itself well to being captured on film. We also only had a limited number of cylinders, and we didn't want slow shutters to foil our quest for proof of hack. Thankfully, digital cameras nowadays come with

RECOMMENDED WEBSITES

For more information on the Roboreptile, go to
www.roboreptileonline.com
www.wowwee.com

movie filming capability, and we were at least able to capture the Roboreptile's best impression of the Big Bad Wolf on video.

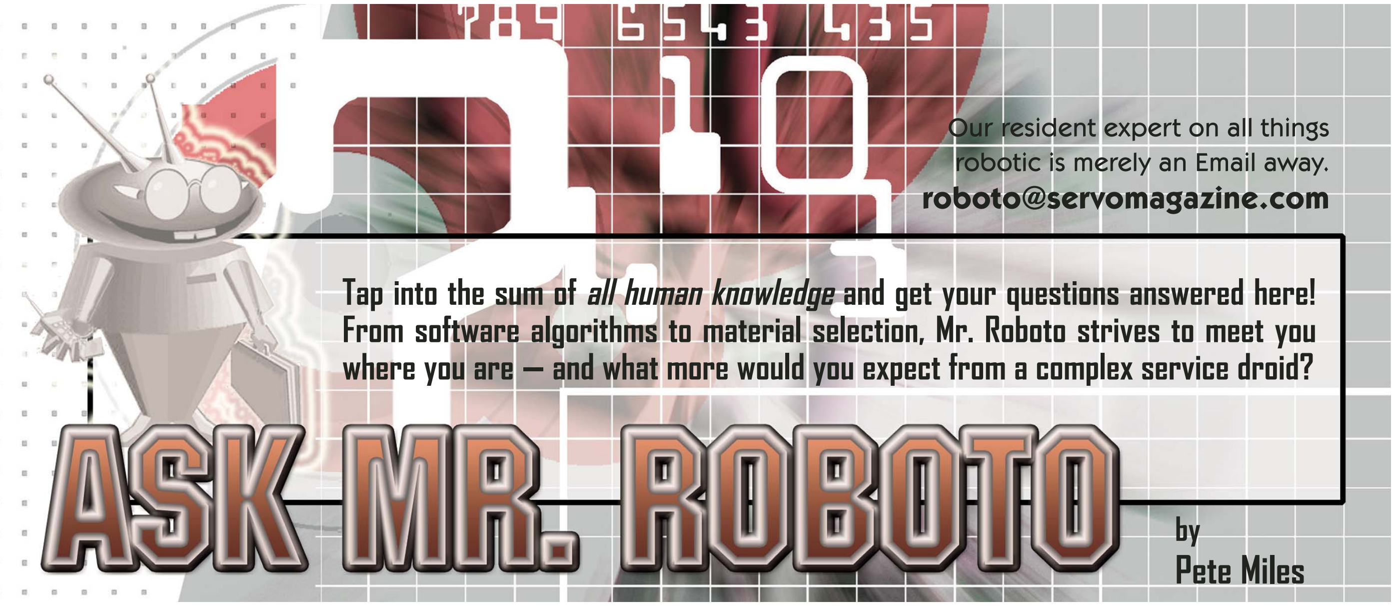
Reverse Evolution

So, what has been gained by the reverse evolution of the humanoid Robosapien to the reptilian Roboreptile? We think the most apparent improvement is in the movement of the precocious dinosaur. The Robosapien was impressive with its two legged walking capability, but we think that the difficulty of achieving this motion is lost on many of the kids that get the Robosapien simply as a toy. The Roboreptile is fast, vocal, and more lifelike with its reptilian prowl than the Robosapien was with its lumbering gait. In this sense, we think it plays to its target audience a lot more effectively. But what about the other possible target audience — the tenacious tinkerers, eager to capitalize on the potential expandability of the reptile?

Perhaps our greatest criticism of the Roboreptile is the disconnect between the audience it targets as a toy and the audience it targets as an expandable platform. Surely the Roboreptile could be entertaining for all ages, but the target demographic for the toy half of the dino is certainly of the younger set. As for the other demographic, the Roboreptile is really only suitable as an expandable platform for those with some tinkering knowledge under their belts. With no easy free ports to use, hackers must go to great lengths that including soldering on their own pins to the board if they want to add any serious extra abilities to the Roboreptile.

Such demands can only be realistically made of a demographic more experienced with electronics than the kids that will get the Roboreptile as a toy. Perhaps we're being a bit quixotic, but what we might have liked to see would have been a platform that was a bit more accessible to the younger group, one that could have initially appealed as a toy, but once opened up, could easily introduce even novice tinkerers to simple electronics experimentation.

Our investigation of the Roboreptile has led us to believe that WowWee made the decision to appeal to casual fun seekers and serious electronics buffs separately, but this should still be an effective strategy if the success enjoyed by the Robosapien in both groups is any indication. At any rate, the overall intention behind the Roboreptile seems to have been "make an entertaining toy," and WowWee has certainly succeeded in that department. **SV**



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ASK MR. ROBOTO

by
Pete Miles

Q. I have been a subscriber since the beginning and have built several small robots, but don't recall ever seeing any info on a stall sensor for robots. I note that the Scribbler has one and wonder how it is implemented.

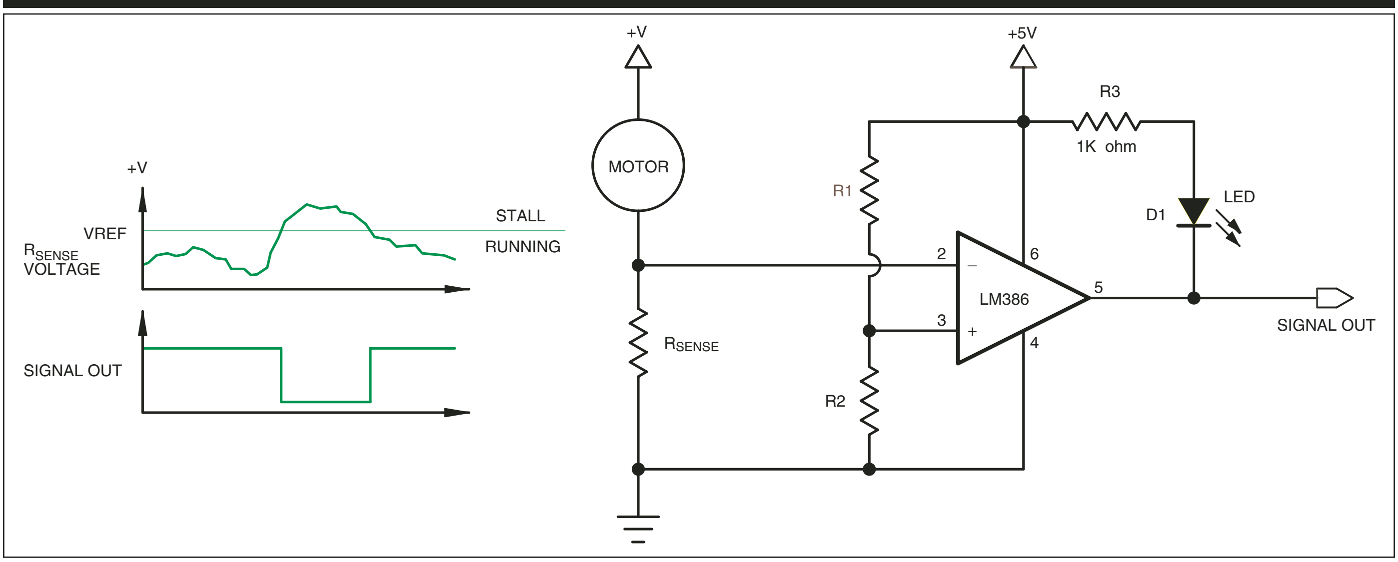
— Ted Poulos

A. First off, let's start with a little background on what a stall sensor is for those who don't know. A stall sensor is a sensor that monitors the current draw from the motors of a robot so that the main microcontroller can turn the motors off to ensure that they are not damaged if they become stalled, or overheated. By definition, a stalled motor is a motor that is not turning even though the power to the motor has been turned on. Stalling a motor is the worst-case situation for a motor, and will result in permanent damage to the motor if it is stalled for too long of a period. How much time until failure occurs really depends on the motor and the applied voltage. Also, overworking a motor for a long period of time will slowly overheat the motor, drain the batteries faster, and overheat the motor controller, which will eventually lead to permanent damage to the motors and motor controller. To protect these components, you will want to make sure that the current draw isn't too high for too long of a time period.

In order to monitor this, a current sensor is needed. A stall sensor and a current sensor are essentially the same thing (unless the sensor uses some sort of a mechanical or optical sensing element that is monitoring the wheel's actual physical motion). Some sensors are binary, i.e., they will output a high signal if the current draw is too high (like the one in the Scribbler robot). Others are analog, and will output a voltage that is proportional to the current going through the sensor/motor.

Since I personally don't own a Scribbler robot (**www.scribbler.com**), I don't have any actual hands-on experience with the robot and can't tell you exactly how it works. So, I contacted Parallax (**www.parallax.com**) to get some specific information about how the sensor works, and they put me in

Figure 1. Simple stall sensor circuit.



contact with one of the members of the robot's design and development team at Element Products, Inc. (**www.elementinc.com**). After a couple discussions with them, it turns out that their stall sensor is a lot more complicated than I originally thought it was.

In a nutshell, their stall sensor uses a Sonix SN8P1602 (**www.sonix.com.tw**) eight bit microcontroller along with a 1.0 ohm resistor connected to a comparator to establish a trip detection level referenced to Vcc through a voltage divider. Then, using some special algorithms (written in assembly language), calculations are made based on the magnitude of the current draw from the motors. Then, comparing the pulse width of the measured current draw with the PWM pulse that drives the motors and correcting these calculations against the battery voltage, a stall current trip signal is generated.

As you can see from this description, the stall sensor that the Scribbler robot uses is a fairly advanced circuit. For a commercial product, a stall sensor should be fairly robust and be able to account for current draw variations due to terrain variations (such as carpet, hardwood floors, sand, etc.), hills, sticks, potholes, and walls. In addition, a good stall sensor needs to take into account the state of the battery. As the battery drains, the available voltage to the motors begins to drop. As the voltage drops, the amount of torque needed to stall a motor decreases. A stall sensor that doesn't take into account the voltage state of the batteries may indicate that the motors are still turning because the current draw is less than a preset threshold, when, in fact, the motors are actually stalled due to the lower applied voltage.

Figure 1 shows a schematic for a simple stall sensor. R_{SENSE} is the current-sensing resistor. As a general rule, the value of this resistor should be less than 1/10 the resistance of the motor. If the value is greater than this, then the resistor will start slowing the motor speed. For example, if the R_{SENSE} resistor had the same resistance as the internal resistance of the motor, then the maximum speed of the motor will be half the maximum speed if the R_{SENSE} resistor was not present. In essence, this will act like a voltage divider.

R_1 and R_2 are wired as a voltage divider to establish a reference voltage. This reference voltage is the trigger point that tells you that the motor has stalled. These values are chosen based on what the voltage across the R_{SENSE} resistor is when the motor is near the stall condition. Usually $R_1 > R_2$. When the R_{SENSE} voltage exceeds the reference voltage, the LED will light indicating that the motor has stalled. The output voltage will then drop from the five-volt state to a less-than-one-volt state. A microcontroller can be attached to the output signal line to monitor the state of the motor.

Hopefully, this will help point you in the right direction of how basic stall sensors work. If you want to know the subtle details of how the stall sensor on the Scribbler robot works, you might want to buy one and take it apart. They are fairly inexpensive, so it would be a fun way to learn how they work and have a robot to play with.

Q. I am thinking about making a radio-controlled robot. What's the difference between AM and FM RC systems? Why does everyone say an FM radio is better than an AM radio?

— Joanna Mills

A. Other than the electronics inside the transmitter and receiver, the main difference is in how the commands are transmitted from the transmitter to the receiver. Both systems use radio frequency waves to transmit information through the air. The difference between the two is how this radio frequency wave encodes the information being transmitted. Both systems transmit a basic constant amplitude and constant frequency carrier wave that is at the characteristic frequency of the radio. For example, 27 MHz for most AM radios, 72 MHz for aircraft using FM radios, and 75 MHz for ground vehicles using FM radios.

AM radios use what is called an Amplitude Modulation technique to transmit information. Here, the amplitude of the carrier wave is increased when information is being transmitted, then drops back to normal when no information is being transmitted. To illustrate this, the top of Figure 2 shows a simple characteristic radio frequency being transmitted through the air. The amplitude and frequency is constant in this radio wave. The middle line shows a square wave representing some data that needs to be transmitted. This information is simply transmitted by increasing the amplitude of the carrier wave when the data is in a high state, and dropping back to normal when the data is in a low state. Hence, amplitude modulation. This is illustrated with the AM wave shown at the bottom of Figure 2.

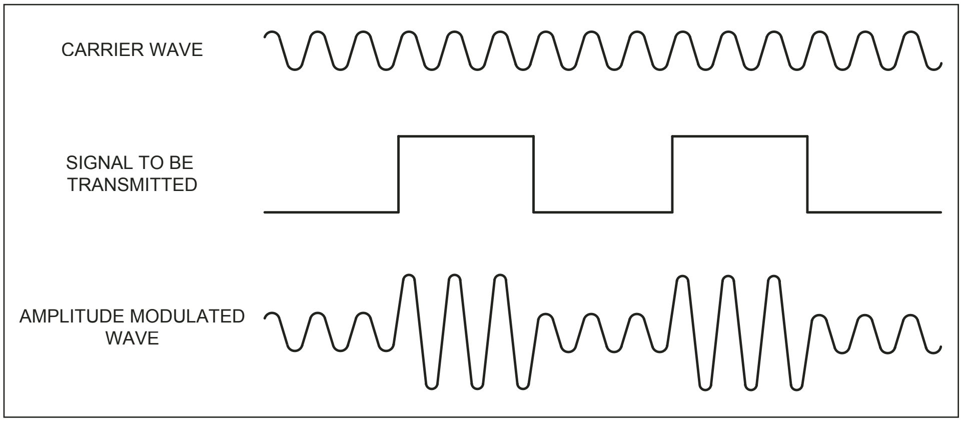


Figure 2. AM radio transmission signals.

FM radios work in much the same way. Instead of amplitude of the carrier wave changing, the frequency is changed. To illustrate this (as in Figure 2), the top of Figure 3 shows a simple characteristic radio frequency being transmitted through the air, and the middle of the Figure shows a square wave representing some data that is being

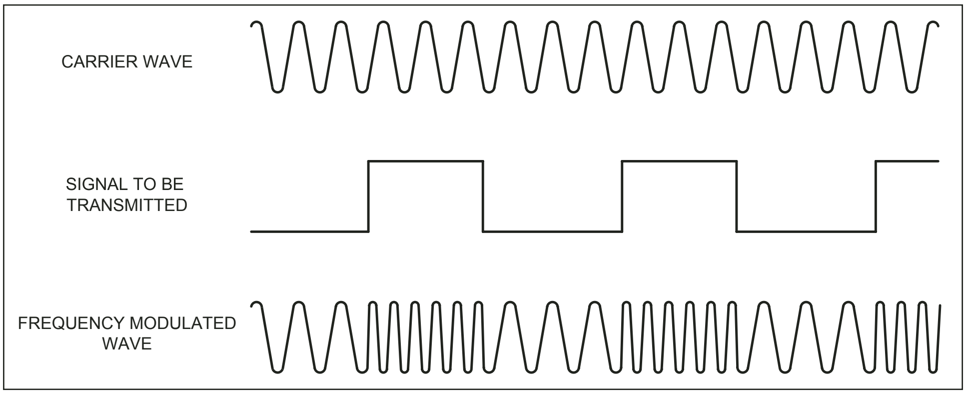


Figure 3. FM radio transmission signals.

transmitted. What is different here, is that when the data is in a high state, the frequency of the carrier wave is increased, and when the data is in a low state, the frequency returns to its normal characteristic frequency. Hence, frequency modulation, which is illustrated with the FM wave at the bottom of Figure 3.

Both of these systems transmit the servo position information the same way. Instead of changing the magnitude of the amplitude in AM systems or varying the frequency in FM systems to be proportional to the desired position of the servo, the duration of the amplitude/frequency change determines the position of the servo. This is known as Pulse Position Modulation, or PPM.

Figure 4 illustrates a simple three-channel AM transmitter (not drawn to scale). The three channels are transmitted sequentially. The pulse width for each channel varies between 1.0 and 2.0 ms, and there is about a 0.5 ms delay between each channel. After the third channel is transmitted, the signal goes low until a total time of 20 ms has elapsed, and the transmit cycle is repeated again. An FM system works the same way except that the frequency is changed instead of the amplitude.

When there is no source of radio interference, both AM and FM systems work quite well. However, since AM systems interpret data based on the amplitude of the signal, the distance between the transmitter and receiver, obstacles between them, and electrical noise interference can alter the transmitted signal. This will cause the receiver to respond to the signal differently than expected.

FM systems are not immune to electrical noise interference, but they are not as sensitive to electrical interference as AM systems. When it comes to having a reliable radio communication link between the transmitter and the robot, a FM radio system is more reliable than an AM radio system. When even more reliability is needed, look at the advanced FM radio systems that use Pulse Code Modulation (PCM) to transmit the data.

A PCM radio converts the pulse width data into binary data, adds a checksum value, and transmits a square wave similar to what is shown in Figure 3. The receiver takes the binary data and compares it with the checksum value, and if any radio interference causes the data not to match up with the checksum value, the data is ignored. This way, the receiver won't respond to bad data like the other systems do. It is better for a robot not to respond to bad data than having it do unexpected things if it received a bad signal.

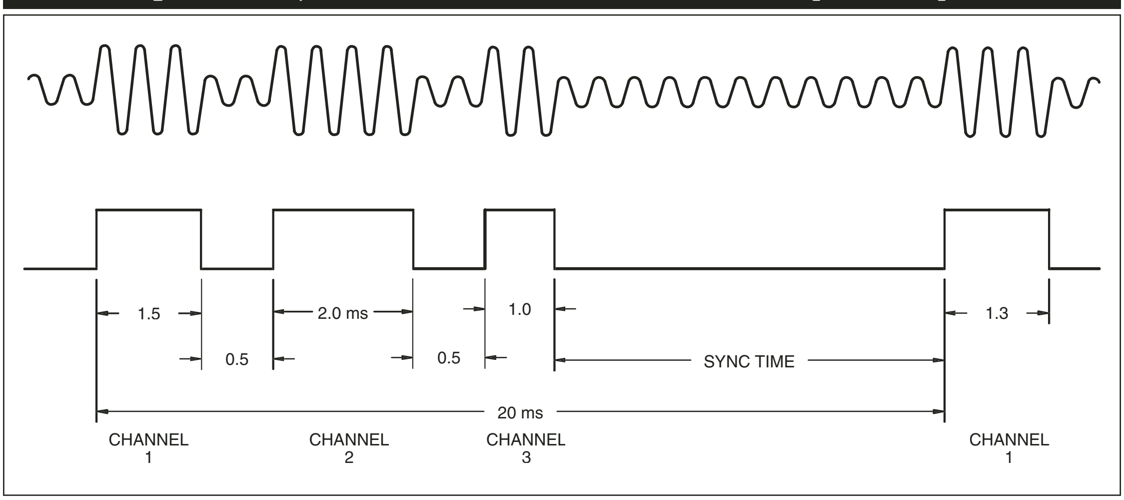
Q. How do you make a light sensor work?

— Janet Kawalski

A. Probably the easiest way to do this is to use a Cadmium Sulfide (CdS) cell, which is also known as a photoresistor or photocell. Photoresistors are an optical version of a potentiometer. Instead of mechanically turning a knob to change the resistance in a potentiometer, changing the light intensity changes the resistance in a photoresistor. The photocell's resistance is inversely proportional to the light intensity, where the resistance is at the maximum value in total darkness and rapidly drops down to less than 50 ohms in direct sunlight. Depending on which CdS cell part number you have, the maximum resistance can range from 100K to as high as 20 megohms.

Photoresistors are typically wired into a voltage divider circuit so that as the resistance of the photocell changes, the output voltage will change proportionally. Figure 5A shows a simple schematic that illustrates how the sensor is wired. The value of

Figure 4. Pulse position modulation of an AM radio transmission signal (PPM Signal).



resistor R_1 is arbitrary since it depends on the resistance range of the CdS cell, what is the typical variation of the light intensity the sensor is attempting to monitor, and what is the voltage range your electronics can monitor. Generally, the best resistor value will be one that gives the greatest voltage swing for the normal range of the light intensity changes that the photocell will be monitoring.

The easiest way to determine an appropriate value for R_1 is to use the calibration circuit shown in Figure 5B. With this circuit, the voltage is inversely proportional to the light intensity. In other words, the voltage will decrease as the light intensity increases. To use this circuit, lower the light intensity to its normal darkness, and adjust the potentiometer until the voltage is within about half a volt from the supply voltage. Then raise the light intensity to its normal maximum value (sometimes this requires moving the sensor to the light source). Adjust the potentiometer to some low setting, say, one volt. This brackets the resistor value range for your setup. Then, repeat this process a few more times, but don't adjust the resistor as much each time. At some point, you will find a potentiometer position that will give you the biggest voltage swing to the different lighting condition changes. Once this potentiometer position is found, then the proper R_1 resistance can be measured, then the final circuit can be made.

These sensors are inexpensive and can detect a wide variation of light changes, so using a lot of these sensors at one time will provide a lot of sensor data on the various intensities of the light, and be able to locate the brightest and darkest areas. SV

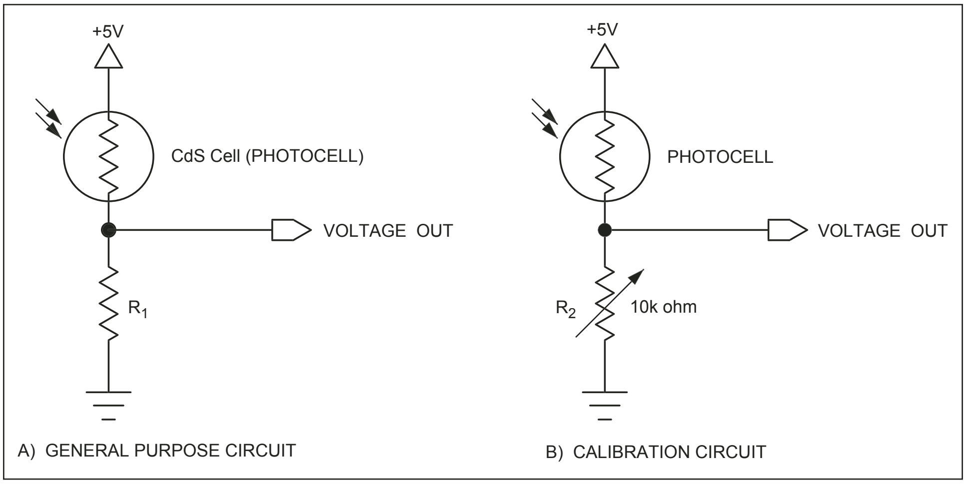


Figure 5. Simple photocell wiring setup.

Programmable Logic:

by Gerard Fonte

The goal of this bimonthly column is to provide a basic understanding of the various programmable logic techniques.

There are a lot of powerful low-cost components available today that are rarely considered by hobbyists — and even some engineers — because of unfamiliarity.

You have to be comfortable with the idea and concepts of programmable logic before you will be likely to employ them.

Counters

This installment on programmable logic concerns counters. There are different types of counters that you can choose for your design. Knowing the characteristics, strengths, and weaknesses of these counters is important in using them properly. While this article is geared towards programmable logic, many of the ideas are directly applicable to discrete digital design.

Counter Basics

A counter is basically a finite state machine. This is a complicated way of saying that a counter has a memory of what has happened in the past and will act accordingly in the future. For example, it knows that the last count was seven and the next count should be eight. This is very different from an AND gate which only reacts to the values presented at its inputs at the moment.

The simplest counter is a one-bit counter, shown in Figure 1. It has two states: low and high. As a counter, these two states typically represent zero and one, but this is arbitrary. Note that the input does not have to be a nice, regular signal. This counter reacts to the negative going edge of the input signal and ignores everything else (other counters may react to the positive going edge). Every standard counter is sensitive to the edge of a signal rather than to a steady-state logic level.

Note that the output is fed back into the input. Feedback of some sort is normally necessary for every type of counter. This feedback determines the maximum counting speed of the counter. No digital switch can act instantaneously. Therefore, there will be a small delay from when the input edge is presented to the counter and when it appears at the output. The same is true for the inverter. Additionally, there is some small time required for the flip-flip to accept a change at the Data input. This is called "set-up time."

Let's suppose that all of these times

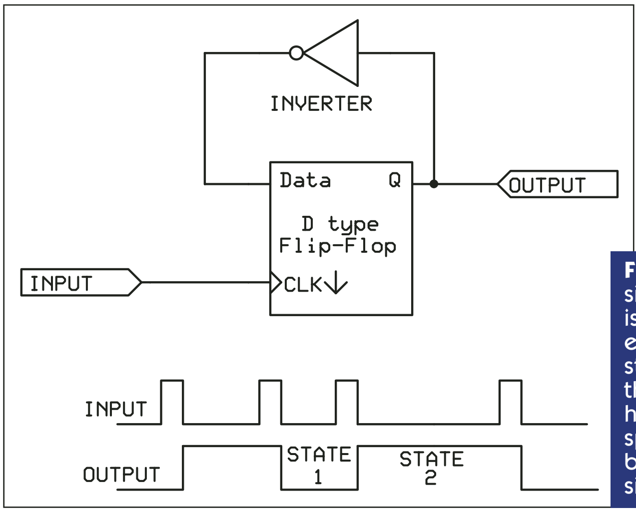


FIGURE 1. The circuit for a simple one-bit counter. It is sensitive to the clock edge rather than to its steady-state value. Also, the input signal does not have to have evenly-spaced edges. The feedback is an important consideration for all counters.

summed together equal 50 nS. This means that the counter will not count properly if two negative going edges occur within 50 nS. This is another way of saying that the maximum counting speed is 20 MHz. This idea of feedback delay is an important concept that will be revisited often. It is the main speed limiting factor in counter design.

Figure 2 shows three simple, one-bit counters connected in series. This configuration is called an asynchronous ripple counter because the output from one one-bit counter ripples on down the line of counters. Note that the output of the three counters together creates the standard binary counting sequence. This is very useful. This also means that the maximum possible number of states is created with this counter. This is also useful. (The maximum number of states is 2^N where N is the number of bits used.)

It's asynchronous because the outputs change at different times. There's a slight delay from the falling edge to the output of "A." Then, there's another delay for "B" and another for "C." These delays may be short, but they are very troublesome. If you want to read the counter, you will have to wait until the count ripples all the way through the last bit. For a counter of 20 bits, this means perhaps 600 nS or a maximum counting frequency of 1.6 MHz. This is very different from the 20 MHz counting rate above. Additionally, these delays vary according to temperature and supply voltage. This is not useful.

Counter vs. Divider

Counting speed is usually measured by the time it takes from applying an input edge until all of the counter outputs are stable. So it's important to note that while the multi-bit counter above will operate properly at 20 MHz, it can't be read at that rate. This defines the difference between a divider and a counter. A divider reduces an input frequency by some factor. In most instances, the delay is not important. Counter ICs are often used as dividers as well as counters. In fact, the circuits can be identical.

However, the counter function presents a value associated with the number of input edges detected. A counter must be read whereas a divider isn't read. This reading of the counter value is why the outputs of the counter need to be stable. An unstable value is not readable or useable. For the rest of this article, we will examine only counters. (There's a future article on dividers and timers.)

Asynchronous vs. Synchronous Counters

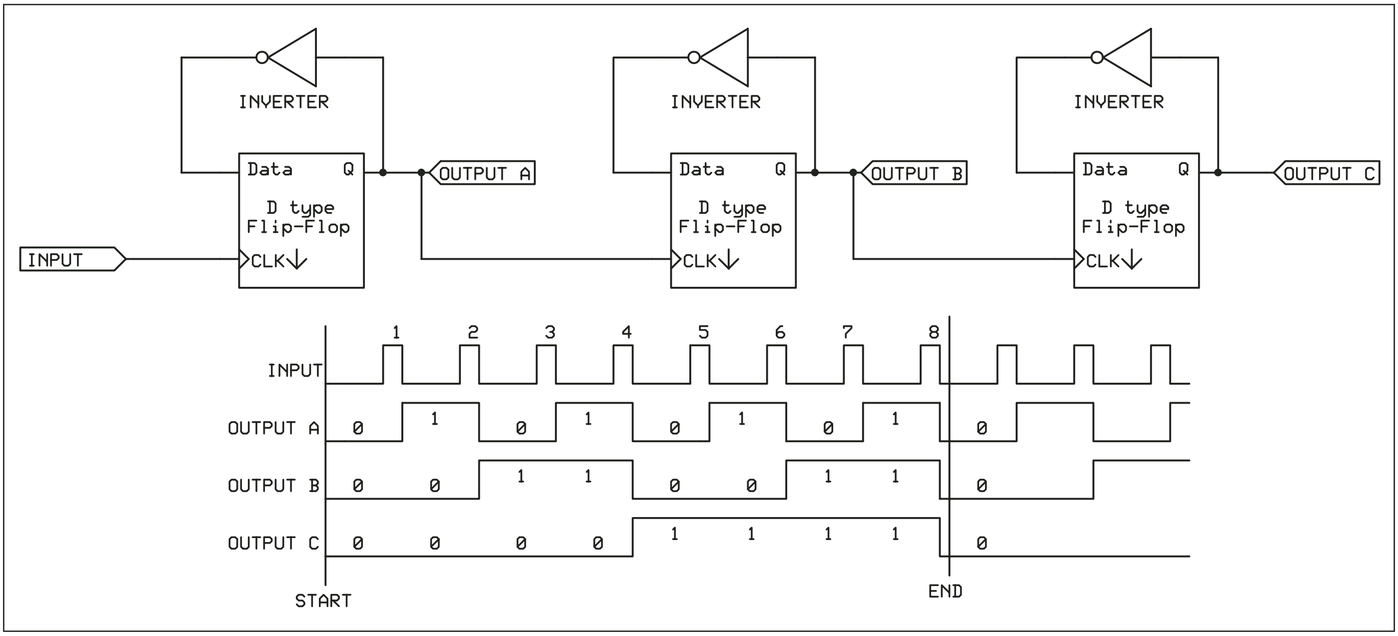
As shown in Figure 2, an asynchronous counter's bits change at slightly different times. A synchronous counter changes all of its bits at the same time. A simple way of determining if a counter is synchronous or asynchronous is to examine how the bits are clocked. If all the bits are clocked with the same signal, then the counter is synchronous. If different signals clock different bits, then the counter is asynchronous.

Since the outputs of an asynchronous counter change at slightly different times, serious glitches can be created when trying to decode particular states. For example, suppose you are decoding the zero-state (000) of a three-bit counter like the one shown in Figure 2. Presume that the counter is at 001 and another clock is detected. The low-order bit will change first, causing the output to go to 000 until the next flip-flip can respond. After a few nanoseconds, the next bit will change creating the proper value of 010.

These few nanoseconds can cause a devastating effect on your system by making it think it's at state 000 when it's not. Additionally, finding this glitch of a few nanoseconds is not always easy. In short, be extremely careful when decoding the output states of any type of asynchronous counter. They bite.

There is an interesting property of counters that use a binary sequence. If you invert the outputs, the counting sequence is reversed. That is, they

FIGURE 2. Three simple counters are cascaded to create a three-bit ripple counter. The timing diagram illustrates the binary pattern that is generated which is a very useful feature. This is an asynchronous counter because different clock signals are used for different bits.



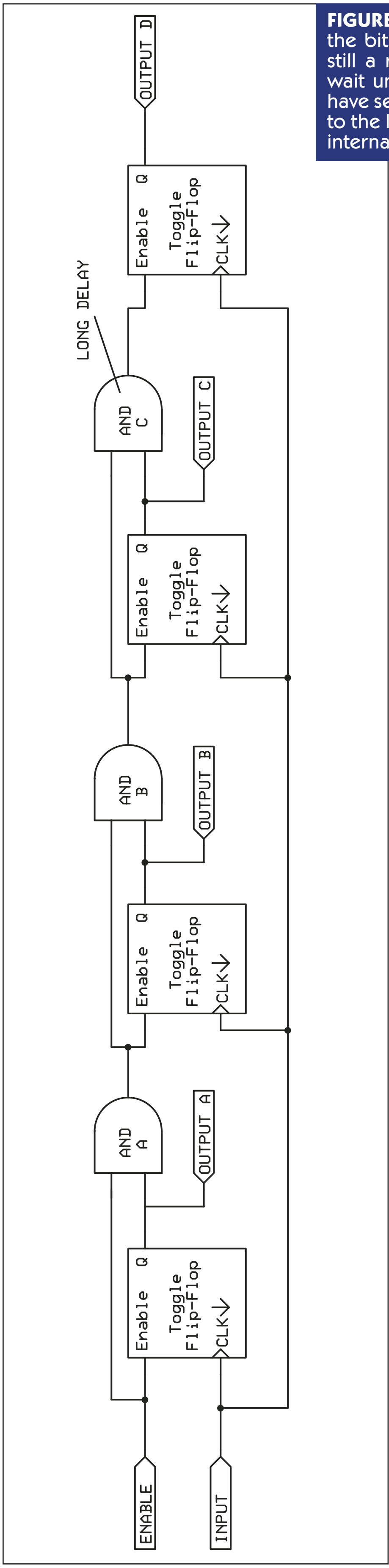


FIGURE 3. This is a four-bit synchronous counter (all the bits are clocked with the same signal). This is still a ripple counter because AND-gate "C" must wait until all of the preceding gates and flip-flops have settled before it can provide the proper signal to the last flip-flop. Note that "toggle" flip-flips have internal feedback that is not shown.

count down rather than up. If both the inverted outputs and non-inverted outputs are used, the up/down count relationships are locked as complimentary values (always summing to all ones). This feature can be very useful.

As noted previously, Figure 2 is an asynchronous ripple counter. Figure 3 shows a synchronous ripple counter. Note that there is only a single clock signal going to all the flip-flips. (This toggle flip-flop will change state on the falling clock edge only if the enable signal is high.) This means that there is a very small delay between when the counter is clocked and when the outputs become stable. Additionally, this delay is virtually identical for each bit. That is, all the bits change synchronously or at the same time.

However, the maximum speed is not much better than Figure 2. This is because there is still a signal that has to ripple down through a number of flip-flops and gates. This is the enable signal to the last flip-flip. It must wait for every gate and flip-flip preceding it to become stable. This is evident through the series-connected AND gates. So while this approach provides an easy-to-read counter, it does little to improve the useable speed of the counter. (Note as a divider, this design is distinctly inferior to Figure 2.)

An important point to note is that the signal needed to allow a flip-flop to toggle is the same as the "carry" signal in the standard binary counting sequence. For example, the third bit changes on the count after 0011 (0011 to 0100). Thus, Figure 3 is sometimes called a "ripple carry" counter.

There is a partial solution to the ripple problem. This is the "Look Ahead" counter. Instead of waiting for the AND gates and previous flip-flops to settle, the idea is to predict when a flip-flop will change and anticipate it, or look ahead in the count. So, if the first two bits are high, then on the next count, the third flip-flop should change. This look-ahead method allows a full clock period for the counter to settle.

Fundamentally, this involves decoding the previous state of the counter (this was detailed in an earlier article). The problem is that every preceding bit of the counter must be decoded in order to provide a proper signal to the working bit. This is workable for a few bits. But when the counter is 20 or 30 bits long, this approach is usually not practical. Most typically, long binary counters are made up of a series of look-ahead counters of eight bits or less. This is a compromise between complexity and speed.

Johnson Counters

A Johnson counter — also known as a ring counter — is a synchronous counter with a non-binary sequence. It's basically a shift register with feedback as shown in Figure 4. Johnson counters have a lot of nice features. The first feature has already been noted — it's synchronous. This is seen by the common clock line. The second is that

TABLE 1. The counting sequence for a four-bit Johnson counter. Only eight of the 16 possible states are used. Note that each output has the same pattern but the pattern is delayed relative to other bits. This is a useful feature.

COUNT	OUTPUT A	OUTPUT B	OUTPUT C	OUTPUT D
0	0	0	0	0
1	1	0	0	0
2	1	1	0	0
3	1	1	1	0
4	1	1	1	1
5	0	1	1	1
6	0	0	1	1
7	0	0	0	1
0 (INITIAL STATE)	0	0	0	0

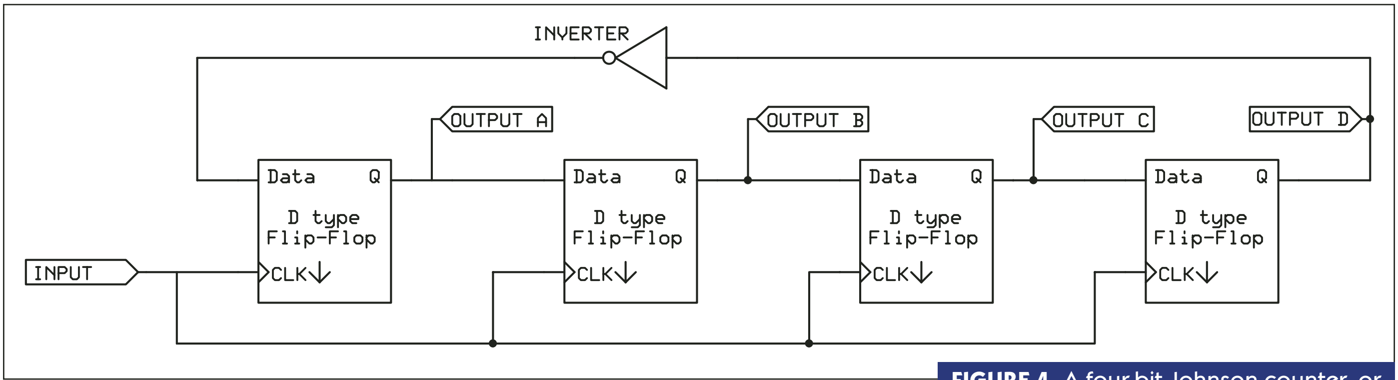


FIGURE 4. A four-bit Johnson counter, or ring counter, is synchronous, simple, and fast. It doesn't count in a binary pattern (see Table 1) and uses only a fraction of all the possible binary states. It is very useful for controlling state machines and/or motors.

it's very fast. There is no ripple characteristic. The single feedback inverter is actually very similar to a one-bit counter (Figure 1). The counting sequence (shown in Table 1) only changes one bit at a time. This is useful because fewer transitions means less power and less power-supply noise generation. This sequence also allows a simple two-input gate to decode any particular state, regardless of the length of the counter.

The bad news is that it only counts a fraction of all possible states. Specifically, it can only count to 2N states (where N is the number of bits). So it you want to count up to 1,000, you will need 500 flip-flops. Clearly, this is not practical for large counters. Additionally, if something should happen and a flip-flop change inappropriately (due to noise, for example), that change can be propagated forever. It just keeps on going around and around and around ...

However, Johnson counters are extremely useful for controlling state machines or sequential operations. Additionally, their outputs show a constant relationship to each other. This relationship can be defined as a phase angle since each output is actually the same but delayed by some amount (relative to each other).

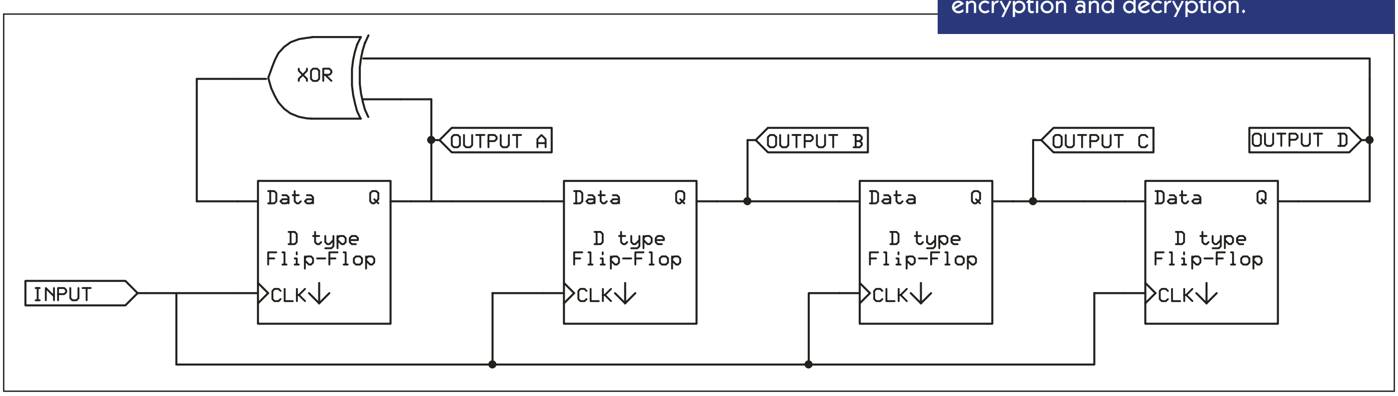
The amount of phase delay depends upon the number of bits in the counter and which output-bit is used. A three-bit Johnson counter can automatically create three-phase signals similar to a three-phase power line. Multiple-pole motor signals can be generated very easily. And the motor speed can be controlled by simply changing the input frequency.

The Linear Feedback Shift Register

The Linear Feedback Shift Register (LFSR) is a poorly known type of counter. It has many good qualities and one large bad feature. As shown in Figure 5, the LSFR appears to be very similar to the Johnson counter. Like a Johnson counter, it's extremely fast with a simple feedback path (no ripple), it's synchronous, it can be arbitrarily long with no loss in performance, and it changes only one bit at a time. Unlike a Johnson counter, it produces nearly a full complement of binary states. Specifically, it can produce (2^N)-1 counts (where N is the number of bits). This is exactly one less than the complete binary set. Thus, an eight-bit LSFR counter has 255 states rather than the 256 states for a binary counter. The one state missing is the "stuck state" where the counter refuses to function. In Figure 5, the stuck state is all zeros. Should this state be encountered, the counter will maintain the all zero state forever. Note if an XNOR gate is used instead of the XOR gate in Figure 5, the stuck state is all ones. In normal operation, the LSFR automatically skips the stuck state.

Figure 5 shows a single gate feedback. For longer counters, a number of bits must be XORed (or XNORed) together. But this number is small. For counter lengths up to 40 bits: 23 use two bits for feedback (like Figure 5), 14 require four bits, and only one employs six bits (that's the 37-bit counter). Unfortunately, there is no easy way to identify exactly what bits should be used for the feedback. If the wrong ones are chosen, the counter may not

FIGURE 5. The four-bit LSFR counter is synchronous, simple, and fast. It incorporates all the binary states except one "stuck state." In this case, the stuck state is 0000. For larger counters, its operation is not obvious and the feedback choices are not intuitive. It counts in a pseudo-random pattern. However, this can be very useful for encryption and decryption.



SIZE (N)	FEEDBACK BITS	SIZE (N)	FEEDBACK BITS
3	3, 2	22	22, 21
4	4, 3	23	23, 18
5	5, 3	24	24, 23, 22, 17
6	6, 5	25	25, 22
7	7, 6	26	26, 6, 2, 1
8	8, 6, 5, 4	27	27, 5, 2, 1
9	9, 5	28	28, 25
10	10, 7	29	29, 27
11	11, 9	30	30, 6, 4, 1
12	12, 6, 4, 1	31	31, 28
13	13, 4, 3, 1	32	32, 22, 2, 1
14	14, 5, 3, 1	33	33, 20
15	15, 14	34	34, 27, 2, 1
16	16, 15, 13, 4	35	35, 33
17	17, 14	36	36, 25
18	18, 11	37	37, 5, 4, 3, 2, 1
19	19, 6, 2, 1	38	38, 6, 5, 1
20	20, 17	39	39, 35
21	21, 19	40	40, 5, 4, 3

TABLE 2. The feedback bits for various-length LSFR counters. This assumes that an XNOR feedback gate is used. Also, the bit number starts at 1 (rather than 0).

produce the full complement of states.

Sometimes there is more than one set that will produce the maximum number of states. But the counting sequences are completely different. Table 2 shows the XNOR feedback bits for counters of three bits to 40 bits (from the Xilinx 1994 data book). Additional LSFR references are provided at the end of the article.

The bad feature is that the counter has a non-binary counting sequence. Worse, the sequence can appear to be completely random and is not at all predictable. Different feedback choices yield different counting patterns. XOR and XNOR feedback also results in different counting sequences. Nor is there any obvious relationship between the counting patterns of short LSFR counters versus long LSFR counters. However, there are many applications where random numbers are useful. This is seen in data encryption and decryption, for example.

You can buy all sorts of binary counters. There are a number of Johnson counters available. However, there are no LSFR counters that I am aware of. This doesn't mean that they aren't important or useful. The LSFR has unique properties and it's easy to implement (even in software ... how about a white noise generator for your micro?). While the LSFR is uncommon, understanding it and knowing when to apply it is useful.

Conclusion

This has been a brief discussion on various counter types. Many details and topics have been omitted because of space. Additionally, there are many methods to deal with the problems of various counters that are not discussed. Nevertheless, counters are required in the vast majority of digital designs. Being able to choose a proper counter can be critical in making a successful design. Conversely, using the wrong counter can create all sorts of problems. **SV**

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SOFTWARE

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Franson Technology has released Franson GpsGate 2.0, a Windows and PocketPC utility that lets you run several GPS applications using a single GPS. New features in GpsGate 2.0 are the ability to share a GPS over ActiveSync or Bluetooth. There is support for Garmin software and GPS receivers. GpsGate 2.0 will let you connect Google Earth to a normal GPS, something that otherwise isn't possible.

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In addition to sharing, simulating, and logging GPS functions, Franson GpsGate can be used to perform a number of specialized GPS-related functions. For example, many NMEA GPS applications cannot communicate with the Garmin GPS 18 because it is a USB device. Franson GpsGate lets you connect your USB hardware and GPS software. Franson GpsGate can be used by people on a LAN, with several mobile Windows computers and a single GPS device.

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COMBAT ZONE

Special Welding Edition

Featured This Month

Product Reviews

WHAT HAPPENED TO THE COMBAT ZONE?

Climb back down off the ceiling, faithful readers. Next month, the usual format for Combat Zone will return. And, rest assured, this isn't just a case of "change for change's sake." For the September 2006 issue, I put out a call to the combat community for an article on welding safety, which Steven Nelson quickly produced. However, for the first time since *SERVO* started Combat Zone, we were deluged with requests for articles. All on welding. We reserved the November Combat Zone (just in time for Christmas lists) for a special edition on welding. Welding is a basic shop skill for building bots, like soldering and using machine tools. The community appears to be hungry for advice on techniques and equipment. So we put out a more general call for articles.

Some of the best welders in our game responded with a range of articles, for welders ranging from complete newbies (like yours truly) to veterans wanting to expand their skills. Since my own experience was gained on a farm, using a rusty arc welder and clothes hanger wire, gobbing and dripping wads onto even rustier equipment, you'll notice I didn't contribute anything to this issue!

Builders and lovers of robot combat, the Combat Zone is your resource. If there are other topics you'd like to see discussed, please email them to *SERVO*. We'll try to accommodate any reasonable requests and, let's face it, the unreasonable ones are always good for a laugh! (Not that we would, of course. Well, not much anyway. We are human, evidence to the contrary not withstanding.)

— Kevin Berry

EVENTS

RESULTS — August 14 - September 11

Saturday Night Fights 2.1 was held in Pasadena, CA on August 26th. All bots were antweights. Results are as follows:

- 1st: "Unblinking Eye," spinner, Hammer Bros; 2nd: "Corrosive," spinner, Think Tank; 3rd: "VDD-kit," spinner, Think Tank.

Pound of Pain 11, House of Pop was held in Nashua, NH on August 19th. Twenty-one bots were registered. Results are as follows:

- *Beetleweights* — 1st: "Ripblade," spinner, Sawzall; 2nd: "Pressure Point," claw, JandA; 3rd: "Scrambled Eggs Revenge," spinner, Timber Wolf.

- *Hobbyweights* — 1st: "Darkblade," spinner, Sawzall; 2nd: "LTFD," wedge, Red Dawn; 3rd: "Acute Pain," wedge, Ministry of Bad Ideas.

- *Featherweights* — 1st: "DE Ripper," drum, JandA; 2nd: "Oni Goroshi," spinner, Diginati; 3rd: "TRIPolar," full body spinner, Brain Damage.

House of Slackers was held in Glen Rock, NJ on September 2nd. Twenty-two bots participated. Results are as follows:

- *Antweights* — 1st: "Sweet Revenge," spinner, Slackers United; 2nd: "Yelo," drum, Pinq; 3rd: "Box #5," spinner, Danger Zone.

- *Beetleweights* — 1st: "Primus," beater, Danger Zone; 2nd: "D12," wedge, Headbangers; 3rd: "Dancer," drum, Crazy Dad.

- *Hobbyweights* — 1st: "Rants Pants," wedge, Not-So-Boring Robots; 2nd: "George," wedge, George Hotz; 3rd: "Ray," wedge, Ray Barsa.

The Texas Cup was held on September 9 in Carrolton, TX. Forty-five bots were registered. Results are as follows (only first place listed):

- *UK Ant* — DM-150, spinner, Discover Magnetics.

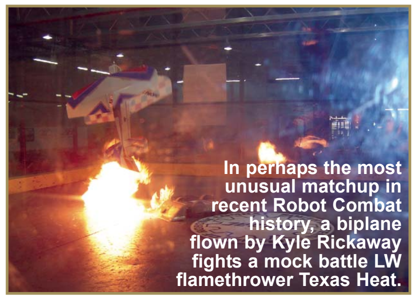
- *Antweight* — Dark Pounder, spinner, Dark Forces.

- *Beetleweight* — DM-E, spinner, Discover Magnetics.

- *Hobbyweight* — Scoopula, wedge, Slaughterhouse.

- *Lightweight* — Spinner Bait Jr, wedge, Teamxd.

- *Middleweight* — Sub Zero, flipper, Hammertime. **SV**



In perhaps the most unusual matchup in recent Robot Combat history, a biplane flown by Kyle Rickaway fights a mock battle LW flamethrower Texas Heat.

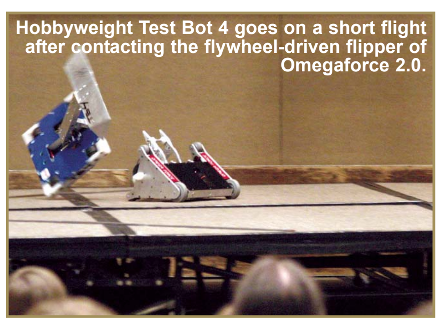
Destruction at Robot Battles: Nuclear Kitten sends Lollerskates back to the pits as a "robot kit."

Robot Battles at Dragon*Con 2006 — Results

● by Charles Guan

Over Labor Day weekend, the place to party if you're a botter is at the Robot Battles event, held annually alongside the Dragon*Con sci-fi and comic convention in downtown Atlanta, GA. Here, the competition is more show than hardcore tournament, and the event is a blend of arena full-weapon destruction and an elevated-stage sumo contest where innovation and driving skill dominate. This year's results are as follows:

- *Antweights* — 1st: "Lab Rat," pneumatic flipper, Lab Rat Revolt;



Hobbyweight Test Bot 4 goes on a short flight after contacting the flywheel-driven flipper of Omegaforce 2.0.

2nd: "Emoticon," lifter, Hockeyrunner Robotics.

● *Beetleweights* — 1st: "Chisel," pusher, Blade Robotics; 2nd: "Nuclear Kitten." vertical disc, Team Test Bot.

● *Hobbyweights* — 1st: "Probulator," pneumatic ram, Evil Robots, Inc.; 2nd: "Dagger" articulated pusher, Blade Robotics.

● *Featherweights* — 1st: "iRobob," pusher, Wave Racing; 2nd: "Scimitar," flywheel flipper, Blade Robotics.

● *Hobbyweight Rumble* — "Omegaforce 2," flywheel flipper, Dale's Homemade Robots.

● *Featherweight Rumble* — "Stewiebot," hammer, Hockeyrunner Robotics.

Mark your calendars for next year, because the Robot Battles event is now headed for its 18th year in 2007 and is only getting bigger. Check out the website at **www.robotbattles.com**. SV

WELDING FOR REAL BEGINNERS

● by Bill Bottenberg

When I first started building robots, the only tools I owned were basic hand tools. At some point, it became apparent that welding would be a handy capability for my bot building efforts. The following gives my experiences in learning to weld as a low budget, low tech garage (bedroom actually) builder.

It's been a couple of years and my welding equipment hasn't really changed — just added a few things along the way. This article includes discussion of the Harbor Freight (HF) Hobby Arc 110 welder, HF auto-darkening helmet, other related safety gear, and consumables.

Description

Figure 1 shows a picture of the Hobby Arc 110. The selector switch in the upper left corner allows you to select input voltages of 110V or 220V. The switch incorporates a locking feature such that it cannot be switched to a different voltage. The large knob in the center allows you to adjust the output current. At 110V, max is 70A and that's what mine is set to most of the time. The indicator window on the top gives the welding rod diameter based on output current setting. Again, at 70A, the machine says to use a 5/64 inch rod and that's what I use. At 220V, you can use up to a 3/32 inch rod.

Arc welders of this type may also be referred to as stick welders and buzz boxes.

FIGURE 1. Hobby Arc 110 and other welding equipment.

Setup

Circuit breakers and extension cords can be an issue with this welder. I had my electrician install a dedicated 20A circuit because 15A breakers will open under extended use and any significant length of extension cord can make it difficult to strike an arc (tough enough for a beginner). Other things that can help make your job easier are a bucket of water for cooling hot work pieces (put it outside the reach of your welder electrodes), a chemical fire extinguisher (welding sparks seem to have an incredible attraction to flammable materials), and other personal safety gear as discussed later.

Safety Gear

The Hobby Arc comes with a handheld welding shield. Save yourself the frustration and get a real welding helmet. As you can see in Figure 1, this is a bottom of the line HF auto-darkening solar powered welding helmet. Mine still works fine. It's showing some wear and tear but considering the abuse it takes, nothing that wouldn't be expected. The solar power is used to lighten the mask so if it stays dark after welding, try wiping off the faceplate. Looking into a bright light can also cause it to darken (makes sense). Also in Figure 1, you can see some HF welding gloves. I wear cotton clothing to avoid melting anything into my skin. My apron's got a couple of small holes but nothing has gotten through to me yet.

Other Helpful Items

A slag chipping hammer is handy and a serviceable one comes with the Hobby Arc. It's also a combination steel wire brush. Real welders tell me an air tight storage container for storing welding rods is a good idea. A set of welding Vice Grips (or equivalent) is pretty much a

necessity. Heavy duty side cutters are good for snipping off bad pieces of welding rod.

Operation

Cool. You've got your welder, your flaming paint job welding mask, a nice place to weld, and you're ready to try things out. Your Hobby Arc has a ground clamp and an electrode holder. Welding doesn't work without a complete circuit, so clamp your ground clamp to your work piece, preferably in an out-of-the-way position. Put a welding rod in your holder (bare wire end goes in the holder). Check that your work area is clear of flammable objects. With the electrode holder in your hand, turn on the welder. Use a fairly shallow angle and drag the tip of your electrode across the work piece to start an arc. If you were successful in "striking" an arc, you're now welding. Try to keep the tip of the electrode submerged in the molten pool and use small circular motions to move across your work piece. You'll want to move the rod to a more vertical position when actually welding.

If everything went according to plan, you should now have something that looks like Figure 2. The black crud is the slag from the welding rod flux. Use your chipping hammer to knock that off and with a bit of wire brush work, you should have a product similar to that shown in Figure 3. Even more cool, you just welded two pieces of steel together!

There's probably a good chance all did not go well the first time. If you welded the welding rod to your work piece, use your side cutters to cut it off and start over. The flux is brittle so you need to be careful not to knock it all off when you're cutting the rod. In my first attempts, I managed to create lots of sparks but not much actual welding. Keep trying. It doesn't take long to get the hang of striking an arc reliably. I'm told that difficulty striking an arc can sometimes be attributed to damp welding rods (remember that watertight container we mentioned earlier?).


FIGURE 2. Rough weld showing flux and spatter.


FIGURE 3. Weld after chipping hammer and wire brush.

In Figures 2 and 3, note the slightly beveled edges in the joint. This helps get penetration through the work piece. In my humble opinion, it also helps to keep me on track when welding. It's not real obvious in these pictures, but after grinding the bevels, I used my wire brush to clean all the scale and rust from the work area. Shiny metal is best and easiest to weld.

The example in Figure 3 is a classic butt joint. Two pieces of metal butted together at the edges and welded. You will commonly find yourself welding two pieces at right angles to each other. This is a little bit trickier but not too bad. You need to add a little more of a sweeping motion to get better penetration of the vertical piece. As with most things, it's always good to practice a bit on some scrap material to see how things are going to go. Probably welding thin material to thicker material is most difficult. This will take some practice. Don't think that's specific to stick welding

There are many kinds of welding rods. If you're using a Hobby Arc, use the amp guide to get the right diameter rod. I use a 6013 rod, but 6011 will work fine, if not better. There are other options. The folks at your local welding supply can probably give you some idea of the best material for your welder and for the job you need to do. The 6013 was recommended because of the relatively thin gauge (0.065) steel I was planning to weld.

As with many other materials, if you're planning on hardening the work piece, weld it first and harden it later.

Many will tell you, and rightly so, that for proper welding you need to spend some money on a bigger MIG wire feed welder. I have neither the money, space, or power capability in my garage to handle one of these. I love building robots but sometimes compromises have to be made. I think the Hobby Arc 110 is well worth the money invested. It's saved me many times the original cost in hiring a welding shop for small projects. For big stuff, I use the Hobby Arc to tack things together and then take the job to a proper welding shop for the finish welds.

As far as welders go, this unit is small and lightweight. I take it to all events now because it's no real trouble to drag around and finding adequate power is usually not an issue. At our last event, we used it to attach some makeshift wedge skirts to a front end reinforcement angle (darned spinner still got a wheel). Broken off screw? Just put a spot weld on it. You can grind it off the weld almost as fast as removing a screw. Once your welder becomes a familiar tool, I'm sure you'll find many ways to make use of it.

Cost

So what's this all going to cost? Using current prices from the Harbor Freight website (**www.harborfreight.com**), the Hobby Arc 110 is going for $129.99 (mine cost $99.99 on sale). A solar-powered auto-darkening mask is $69.99 (on sale at the time of this writing for $49.99). Welding rods can usually be purchased by the pound at a local welding shop. I buy a good handful

which is about five pounds at $2-$3 a pound. McMaster Carr (**www.mcmaster.com**) also sells welding rods if you do any bot business with them. Harbor Freight welding gloves are currently $9.99 and perfectly useable. That adds up to approximately $210 at Harbor Freight as an initial equipment investment. Another $10 for welding rods (a few come with the welder but not enough to actually accomplish anything) and you're good to go!

For you beginning builders who are considering this welder because of cost, go ahead and get it. It's simple, it's cheap, and it works. You might need a little more time to develop the necessary skills, but if I can do it, anybody can. Let the welding begin! SV

WELDING TITANIUM

● by Paul Reese and Robert Wilburn

Titanium

The use of titanium in today's combat robots is more of a rule than an exception. While there are still excellent examples of winning robots that do not employ titanium components, the vast majority of builders have come to realize the significant advantages this metal offers. It exhibits high strength with a density just over one-half that of steel. Still, fabrication techniques such as welding and machining often present challenges to teams considering its use. Frequently, the simplest solution is to farm this work out to a machine shop with an established reputation in working with titanium. Team Whyachi Robotics in Dorchester, WI is an excellent example of such a resource.

However, building a combat robot at home and performing most, if not all, of the work in the garage still holds a certain fascination to many people and speaks to the roots of this sport. Many teams routinely weld steel and aluminum using both the MIG and TIG process. Welding titanium is another operation that can be successfully performed at home with the proper equipment and techniques. It can be cheaper in the long run than outsourcing the job and nothing can replace the convenience of being able to weld components "on-the-fly" whenever the necessity arises.

The TIG Process

TIG — or Tungsten Inert Gas — is also called Gas Tungsten Arc Welding (GTAW) and is sometimes referred to as *Heliarc*. It is the most prevalent process for permanently joining titanium. A torch with a tungsten electrode is connected to a power source and shielding-gas supply, usually argon. The material to be welded, or work, is grounded to the power source. An arc is initiated between the tungsten and the work, providing sufficient heat to melt the work material. The shielding gas flows from the torch, around the tungsten, and bathes the molten puddle in a protective blanket of inert gas which prevents contamination from the atmosphere. Additional filler material can then be added to the puddle and is generally a similar composition to the parent metal. Techniques for TIG welding titanium differ from those of steel primarily in the shielding gas and cleanliness requirements.

Shielding Gas

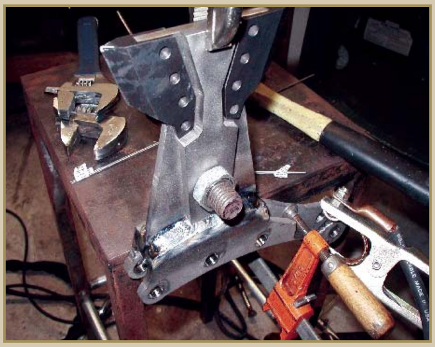
When TIG welding steel or aluminum, the gas supplied by the torch provides adequate protection from atmospheric contamination. A typical flow rate for 1/4" steel might be 13 cubic feet per hour (CFH or ft^3/hr), whereas titanium will require upwards of 25 CFH or more. Hot titanium has an affinity for gases such as oxygen, nitrogen, and hydrogen and will readily absorb these gases from the atmosphere unless precautions are taken. This is true not only for the molten puddle, but for any part of the material above 900°F. Impurities caused by these gases will result in embrittlement and the weld will be prone to cracking. The combat arena is no place to discover a brittle weld that was compromised due to insufficient shielding.

For the ultimate in protection,

Argon bottle with "tee" and dual regulators.

Torch with 3/32" tungsten, large gas lens, and #12 ceramic cup.

Welds in a titanium attachment for 60 lb Ground Zero made from 1/4" 6AL-4V alloy.



Titanium tooth bolted and clamped in preparation for welding.

One of Ground Zero's completed titanium teeth with S7 steel cutters.

Variety of interchangeable titanium teeth for Ground Zero (60 lbs) and KillJoy (120 lbs).

inert gas welding chambers are sometimes utilized where the entire project is contained in a rigid box or flexible "tent" which is filled with argon. Although effective, they can be somewhat cumbersome and are usually unnecessary. Sufficient shielding can be provided by more conventional means.

For example, you should equip your torch with the largest possible cup size (#12 = 12/16 = 3/4") to allow the gas the widest possible area of coverage around the puddle. A gas lens can provide for a less turbulent flow and reduce the chance of atmosphere mixing with the argon. Keep the tungsten close to the puddle because a long arc length promotes turbulent flow. As you move the torch forward, the just-welded area behind the torch is still extremely hot and needs to be protected by shielding gas.

Depending on the thickness of the titanium, the underside of the weld may need protection, as well. A secondary supply of argon is required to provide these auxiliary sources of shielding gas. Tapping off of the main torch regulator is not recommended. However, a "tee" can be used on the output of the argon bottle to feed two independent regulators: one for the torch gas supply and one for the auxiliary or "back-up" supplies.

Trailing Shield

To provide adequate argon coverage of the hot titanium behind the torch, a trailing shield can be employed. As its name implies, this device attaches to the torch and trails behind the puddle for several inches as you weld. A back-up gas supply is connected to the trailing shield, flooding the heat-affected-zone with argon until the material is no longer susceptible to the absorption of atmospheric gases. The argon flow rate to the trailing shield depends on many factors, but it is usually significantly higher than that of the torch; 40+ CFH is not uncommon.

Trailing shields are commercially available, but they can also be fabricated from aluminum or copper. These materials are easy to form and withstand the heat generated by the welding process. A short section of 2" diameter copper pipe cut length-wise will result in two half-pipes that can be used as the basis for an improvised trailing shield. Multiple gas fittings along the length will improve the dispersion characteristics. If a teammate is available during the welding process, he or she can manually position the trailing shield independently and "chase" the torch as you weld instead of attaching it to the torch.

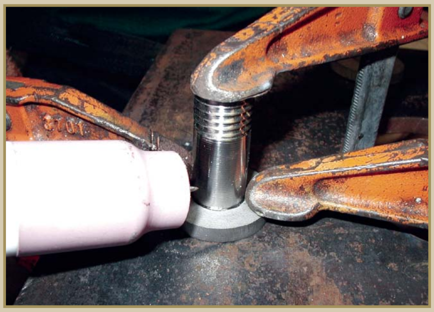
The underside of the weld can also be protected by similar devices. A grooved backing bar or half-pipe can be used for this purpose. Alternatively, metallic foils or tapes may be shaped into a canopy and affixed to the bottom side of the titanium and flooded with argon. All of this can drain a 125 cubic foot argon bottle rapidly.

In all cases, the gas lines feeding the torch, trailing shield, and backside cover should be purged prior to initiating the arc to rid the lines of any atmosphere. An argon blanket should be covering the work before welding begins. Many welders have pre-flow and post-flow settings that can automatically start argon flow to the torch prior to arc start and continue flowing gas for a set period after the arc is extinguished. Post-flow should be no less than 10 seconds to protect the hot titanium. The auxiliary gas sources must be controlled manually. Adequate ventilation is important for safety but you should avoid welding where drafts are present, if possible. This includes outdoors or in your garage with the door up. It isn't worth risking an inopportune breeze at the wrong moment blowing away your shielding gas.

Surface Preparation

Cleanliness is also critical to reliable titanium welding, as even small amounts of impurities will result in brittle welds. The area to be welded and the filler material should be thoroughly cleaned with a lint-free cloth and acetone or isopropyl alcohol. "Pickling" of titanium in nitric acid is sometimes mentioned in literature to remove scale. This is difficult, dangerous, and is often not required for most titanium with a decent surface finish. Plasma or torch cutting titanium will leave an edge with significant impurities that must be dressed by grinding and cleaning prior to welding. Edges resulting from water-jet cutting require minimal attention. Grinding wheels or stainless-steel wire brushes can be used to prepare

Titanium Tooth with S7 steel cutters for KillJoy; weight = 2 lbs, 11.4 oz.



A 3/4" custom-made titainum bolt ready to weld.

Welding the head onto a custom-made 3/4" titainum bolt.

surfaces for welding, but they should not be used on other metals to avoid the transfer of foreign material onto the titanium.

Filler Material

It goes without saying that the titanium used in most combat robots is almost exclusively 6Al-4V grade 5 alloy. It is roughly twice as strong as commercially pure (CP) grade 2 titanium with the same weight. Conventional wisdom is that the filler material should normally match the composition of the parent metal. However, many experts recommend the use of CP rod (ERTi-2) with 6Al-4V parent metal to produce welds with lower hardness, higher ductility, and reduced brittleness. These characteristics are often more desirable than ultimate tensile strength, especially where extreme impacts and high shock loads will be encountered. Moreover, when the 6Al-4V parent material melts and combines with the CP rod, the puddle is effectively alloyed to some degree by the parent material.

Although there is no substitute for proper shielding gas, the use of CP rod can provide a higher degree of tolerance for a limited amount of atmospheric contamination while still producing a weld with reasonable ductility. It takes practice, but the hot end of the filler rod should not be removed from the argon shield while welding to prevent oxidation of the tip. Rods 3/32" in diameter work well for 1/4" titanium while other diameters are available to suit various applications. The tungsten electrode in the torch will often be the same size as the filler rod, but the smallest tungsten that will carry the required current provides better arc control. Thoriated tungsten (2%) should be used for titanium.

Post Weld Examination

The color of the weld can provide clues to the amount of atmospheric contamination in the shielding gas or reveal insufficient coverage. A relatively shiny bead with a silver to straw color indicates successful shielding with minimal impurities. Light blue, gray, or white is indicative of increased contamination and will result in a brittle weld. Interpreting weld quality solely from color can be challenging even to experienced welders. Deposits or build-up near the tip of the tungsten electrode are another indicator of atmospheric intrusion into the argon. X-Ray inspection, hardness testing, and dye penetrant examination are other techniques for evaluating weld quality, but are somewhat impractical for home use.

Welder Selection

TIG welders vary widely in price and offer different capabilities. Transformer based machines are large and heavy while inverter based welders are smaller and lighter. A DC-only unit can be used to weld titanium and steel, but not aluminum; aluminum requires AC output. Harbor Freight Tools offers an inexpensive 130 amp DC inverter-based TIG welder for less than $300. A high quality name brand ~200 amp AC/DC Inverter welder will run $2,000 to $3,000 or more. Like most things, you usually get what you pay for. The Lincoln Invertec V205-T, the Miller Dynasty 200 SD/DX, the Esab Handy TIG 180, and the Thermal Arc Pro Wave 185TSW are just a few examples of quality AC/DC inverter welders. All are capable of welding up to 5/16" titanium and steel, as well as 3/16" aluminum. They are ideal for building combat robots and can easily be transported due to their sub-50 lb heft. Some will even run on 110 VAC in a pinch, but all require a 220 VAC source for serious work. Likewise, a water-cooled torch isn't necessary for occasional light duty use, but will be required for extended operation at high current.

Summary

Welding titanium is not difficult. There is nothing mysterious or exotic about it. It can be performed at home with readily-available materials and equipment. With careful planning and proper attention to shielding and cleanliness, it is as easy to weld as mild steel. By most accounts, aluminum is considerably more difficult. Whether you are an experienced TIG welder or new to the process, there is no reason to shy away from the advantages titanium can bring to your design. **SV**

Paul Reese and Robert Wilburn are Team O-Town Robotics (**www.teamotown.com**). Paul can be reached atnitro_rat@hotmail.com. For more information, contact the Titanium Information Group (**www.titaniuminfogroup.co.uk/**).

WELDING TOOLS AND ACCESSORIES

● by Jeff Vasquez

Okay, so now you have this cool welder. Now what? As always, there is more stuff to buy!

To start with, you'll need some type of table to weld on. I bought a piece of 24" by 30" steel plate that is 1/4" thick. Then I welded a scrap piece of tube to the bottom so my "B & D Workmate" would have something to grab onto. I also drilled and tapped some strategically-placed holes so that I can bolt down jigs and clamps. I simply place the plate on the Workmate and tighten the clamps. This gives me a strong portable table to work on.

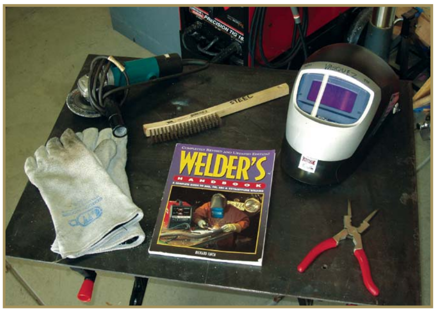
Some of the other accessories and tools that you will need include welding gloves, welder's pliers, an electric grinder, stainless steel wire brushes, and a helmet. Get the best helmet you can afford — preferably an "adjustable auto darkening" one. Auto darkening makes it much easier to weld as you can have the helmet down and see through the glass, but as soon as there is a spark, the helmet darkens to protect your eyes. You don't get second chances with your eyesight so take care of your eyes!

I emphasize "stainless" wire brushes because they don't contaminate the areas that you are cleaning as cheap wire brushes would. Also, mark the brushes "steel," "alum," etc., so you don't cross-contaminate one with the other. Last, but not least, get yourself a copy of *The Welder's Handbook* by Richard Finch. It is full of useful information and explanations with a lot of pictures and diagrams. I refer to it constantly.

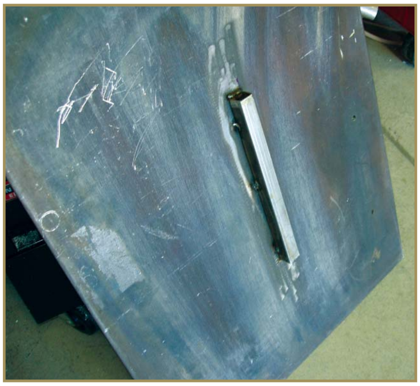
You can never have too many clamps! Get yourself a good selection of "ViceGrip" type clamps of all sizes and types. You will be surprised by how much you use them. Another useful accessory are magnetic right angles. They can be used to hold, line up, and square up pieces of metal. You will find that along with the clamps, corner jigs or straight jigs are very useful. Simply stated, these jigs in conjunction with the clamps hold the metal so you can weld the pieces accurately and safely. SV

Regardless of the type of welding that you do, these clamps and jigs will come in handy. I drilled and taped some holes in the table top to secure the jigs and screw-down type clamps.

These are just a few of the "must have" accessories you will need to start welding safely. Get the best helmet you can afford — preferably with an adjustable "auto darkening" lense. MIG, TIG, GAS, etc., all put out different amounts of light and require different amounts of darkening.



I needed something for the "WorkMate" to grab onto, so I welded a piece of scrape square tube to the bottom.



PRODUCT REVIEWS

Lincoln SP-125 Plus MIG Welder

● by Jeff Vasquez

I am going to tell you what you want to know right at the start. The Lincoln SP-125 Plus and its newer brother the SP-135 Plus are awesome machines that I would recommend to anyone looking for a versatile, high-quality MIG welder that is affordable. When I was looking to buy a MIG welder to start building for Battlebots, I did a lot of research into exactly what I would need and came to the conclusion that a small 110 volt MIG welder would be sufficient to get me going building frames and such. After checking

You can't start them too young — with adult supervision, of course! My son Matthew (Got Robots? shirt) and his friend Dillon take a break from restoring Dillon's dad's old Mustang. Dillon's dad bought his SP-135 on my recomendation!

My SP-125 Plus with the cart. As you can see, the cart comes in handy for storage and holds a bottle of shielding gas quite nicely.

online and at the local welding supply, I decided on the Lincoln SP-125. The newest version of the SP-125 is the SP-135. Everything about it is the same except it now puts out 135 amps.

As supplied from the box, the Lincoln comes with everything you'll need to weld with flux core wire and with gas shielding. The only thing you'll need to buy is a tank of shielding gas as the regulator and hoses for the gas are included. I would highly recommend buying the "Plus" model as it includes the cart which makes moving the rig and handling the gas bottle and tool storage a cinch. With this little gem you'll be able to weld all kinds of steel and even aluminum with the optional aluminum welding kit, although I welded aluminum without it.

What is MIG welding you ask? MIG welding or "wire feed welding" is an ingenious way to make welding fast and simple. To weld, you simply place the gun over the work with about 0.375 inches between the tip and the spot you want to weld. When you pull the trigger on the gun, it activates the positively-charged wire electrode and the shielding gas. The wire feeds out of the gun and contacts the metal to be welded which, in turn, causes a short circuit and an "arc." Shielding gas keeps impurities out of the weld while the wire electrode melts onto the base metal and the whole process starts over, about 60 times per second. This is very simplistic but it works!

This unit allows you to weld with either solid wire and gas (as described above) which makes really nice and neat welds or with "gasless, flux cored wire" which is effective for thicker metals but far more messy (and the welds are not as attractive). The upside to the latter is you don't need shielding gas as the flux is already in the wire.

The only complaint that I have with the unit is that the dials to adjust the wire feed speed and voltage move too easily. It is easy to accidentally change the settings by either moving the machine or inadvertently brushing them with a welding glove. A little more tension on these dials would be helpful.

With tools and equipment, I have always found that you get what you pay for and the Lincoln is no exception. The list price for the SP-135 Plus is about $800, but I've found it for much less on the Internet. Speaking of the Internet, for more info, look at **www.Lincolnelectric.com**. If you want a high quality, 110 volt MIG welder, you won't be disappointed with this unit! **SV**

Lincoln Precision TIG-185 Welder

● by Jeff Vasquez

The Lincoln Precision TIG 185 comes with everything needed to start TIG welding (tungsten inert gas welding) except for a bottle of shielding gas (argon usually), welding gloves, helmet, welding rods, etc. I would highly recommend getting the optional cart as it makes life much easier. The unit lists for about $2,300, but I bought mine new online for much less money with the cart! One thing to remember about this machine is that it runs on 220 volts as most TIG welders do. You will need at least a 50 amp circuit. Adding this circuit to your home is an expense which must be taken into account. The unit also comes with a "cheat sheet" which I've found to be invaluable. Simply find the kind (butt, lap, fillet, etc.) of weld you want and the type and thickness of the metal, and the magic card tells you the type (DC+, DC-, or AC) of current, amount of current, cup orifice, filler rod diameter, tungsten electrode diameter, etc.

While this info is very helpful,

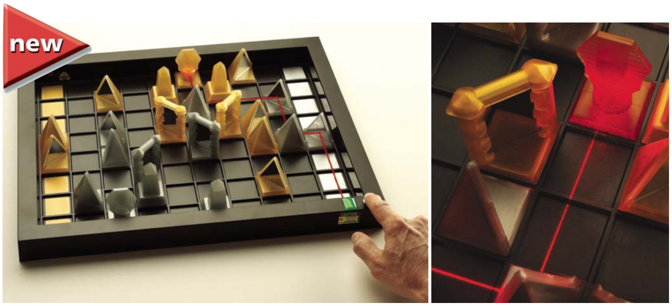
TIG welding is not for beginners. TIG welding is analogous to gas welding. It is said by the experts that if you can weld with gas, you can weld with anything and it is true. Not so much because it's difficult but more so because of the skills and technique involved. With gas welding (oxy/acetylene, etc.), you are using a hot flame to heat the metal. With TIG welding, the principle is the same except you are using electricity. Basically, you are passing a current though the tungsten electrode in the "torch" to a base metal. The result is much like a "spark plug" in an engine and heat is produced. You then feed the welding rod into the molten metal puddle and you have a weld. To weld with a TIG machine you will have the torch in one hand, the welding rod in another, and one foot on the "amptrol" pedal. This pedal allows you to vary the current (up to the set maximum) during the welding process. You can see why TIG is not for beginners! That being said, since I had experience with a MIG welder, I was able to have a friend of mine who knew how to TIG weld pretty well get me started with some basic demonstrations and info.

The Lincoln Precision TIG-185 in all its glory. The optional cart comes in handy to hold the amptrol pedal, the ground cable, etc. The torch hangs on the side. The black "cup holder" on the top flips up for electrode storage. As you can see, everything is clearly laid out for ease of operation.

Back to the machine! My Precision TIG-185 has been flawless and done everything I have asked of it. I have welded mild steel, chromemoly, aluminum, and titanium up to about .250 inch. Thicker metals will require more power than this machine can offer; 99% of the time the SP-185 is powerful enough for everything that I want to do. It is a truly versatile machine that has given me years of flawless service. It has enough bells and whistles to satisfy expert welders doing complicated welds on difficult metals, yet is easy enough to use with the basic controls that even a hack like me can lay down some nice beads. Some of the features include "high frequency" for an easy starting arc and post flow control which lets the gas flow for a set time after you stop welding. This aids in minimizing weld contamination. The "Pulse TIG Control" pulses the current which is useful when working on thin metals. These are just a few of the features of the 185.

The Lincoln Precision TIG-185 is a great machine that I would recommend to anyone who needs a TIG welder. For more info, see the Lincoln Electric website at **www.Lincolnelectric.com**. SV

Discover Why the Brightest Minds Think Edmund...



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XPort Botball Controller Gives Good Game

by Jenny Grigsby, Jorge Villatoro, and Matthew Oelke

To a novice, the world of robotics can be a bit overwhelming. The processors, the building equipment, and the potential programming involved can send a new user screaming into the night. The Xport Botball Controller and its kit would be pretty intimidating, too — if it didn't have the familiar elements of a Game Boy and LEGO bricks.

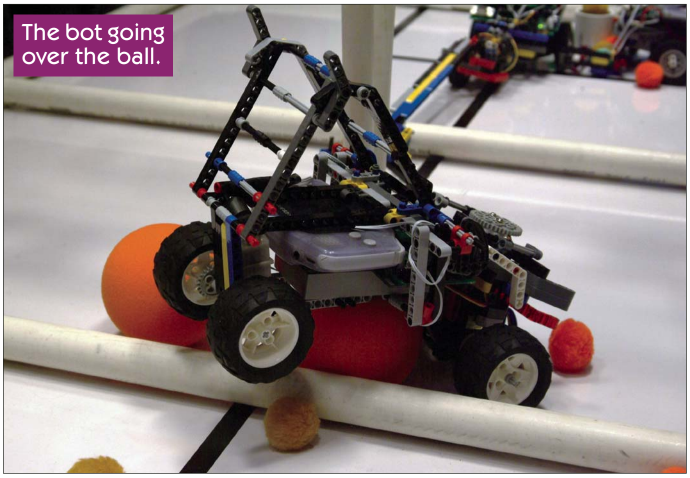
We Got Game (Boy)

The XBC uses a Game Boy (GB) as the main processor. Why? Because of its low price, ease of use, color LCD, and a powerful ARM 7 processor. The element of cool it adds doesn't hurt either. The GB isn't 'hacked' or modified. In a way, the GB thinks the Xport board is a game when it is plugged into the cartridge slot. A user can unplug the Xport, pop in Mario, and concentrate on saving the princess. When the Xport — consisting primarily of a FPGA and Flash memory — is plugged into the GB, the result yields a powerful robotic processor that uses the Interactive C programming environment. Interactive C is widely used today by robotics professionals, hobbyists, educators, and students.

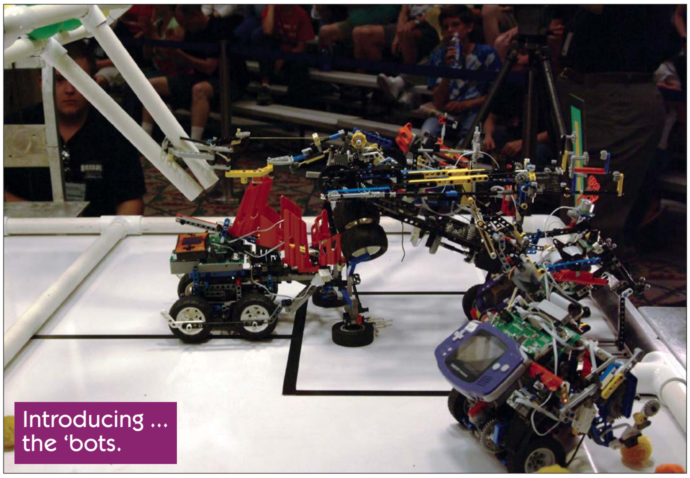
The Xport Botball Controller

The Xport Botball Controller comes by its name because it was primarily designed for the Botball Educational Robotics Program. For the past two years, it is the only processor that the national robotics program has used. The XBC is distributed to teachers every year in the standardized Botball kit. The teachers, in turn, implement the kit and the Botball challenge into their classrooms. The students take over from there — designing, building, and programming original autonomous robots that compete across the country in regional Botball tournaments.

Because Botball is a task game, the XBC is starting to get noticed. The XBC allows middle school and high school students to create incredibly smart and capable robots. A student-built Botball robot can sort different colored objects into various scoring positions using color tracking and vision the same way many industrial assembly processes work. A student-built Botball robot that can maneuver autonomously on the game board mimics robot systems like the Roomba and MER



The bot going over the ball.



Introducing ... the 'bots.

rovers with servos and gear motors.

The XBC is currently gaining national and international attention in the Botball Program and through its use in the NASA Robotics Alliance Project annual summer robotics web course. University programs are utilizing the XBC for classroom, research, and competition activities. The XBC was used to run the Core Sample Handling System for the Mars Astrobiology Research and Technology Experiment (MARTE). The MARTE project developed drilling equipment and programming to extract and interpret the data from rock samples drilled from Mars' surface.

Back-EMF Motor Control

The XBC uses closed-loop motor control that makes use of motion feedback. Back-EMF provides motion feedback to the XBC without incurring extra cost and mechanical complexity, like encoders, or the programming complexity and unreliability of dead reckoning with time. The Back-EMF is based on the electromotive force that occurs in electric motors and some generators and is in direct proportion to its velocity. It is easily measurable by simply cutting power to the motor and measuring the voltage with an analog-to-digital converter.

Since the XBC can measure the back-EMF as well as the amount of time a motor has been running, it can simply integrate the velocity and divide by time to find the distance traveled. In Interactive C, the distance traveled is measured in 'ticks,' or parts of a rotation of a motor. Ticks can be converted to common measurements by dividing by the number of ticks in a revolution of a motor and multiplying by the circumference of the wheel. When armed with that information, it becomes possible to specify the distance and velocity for a motor to turn, thus creating an incredibly accurate robot.

Vision and Color Tracking

In order to keep Botball game development up-to-date with current robotic technologies, a vision system had to be developed that gave the robot the ability to see and track objects during the game without raising the overhead cost.

The XBC can see and track up to three different colors at one time. It does this by using lookup tables inside the FPGA to carry out color pixel filtering. Each selected color uses its own lookup table. This provides the maximum amount of flexibility when selecting color models. The user can select a color with a narrow hue range and designate a broad luminance range. As a result, the color models are strong even with changes to lighting.

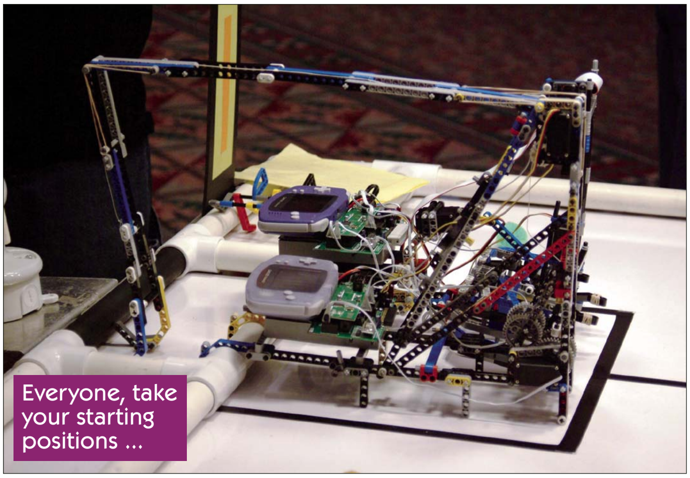
Another useful vision feature is the built-in blob tracking. The XBC is capable of tracking blobs of color and returning information on them. Some of the values returned are X coordinate of the center of the blob, Y coordinate of the center of the blob, the area of the blob, and the locations of the major and minor axis of the blob.

The user interface is very simple. During a Regional Botball Workshop (each regional program begins with a two-day professional development workshop where educators and students are taught how to use the equipment) middle school students, high school students, and their teachers are able to instruct their robots how to play 'Red light, Green light' within a few hours.

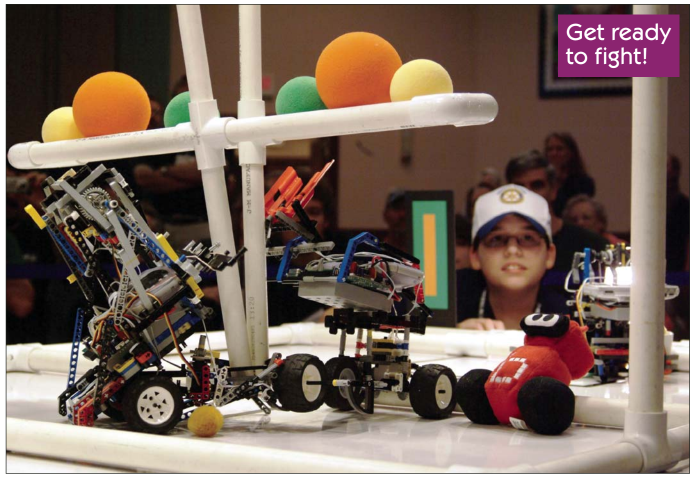
In the Works — Bluetooth

Bluetooth is a technology that is gaining popularity among small device users, because it allows the user to easily connect their devices together, or connect to a computer. This makes Bluetooth perfect for robotic communication applications over short distances. The Bluetooth chip that is available for the XBC allows it to connect wirelessly to any computer with a Bluetooth chip, and future plans include direct communication between XBC units. This connectivity allows for many new applications that may require more than one processor, or more than one set of wheels. An example might be a robot that offloads the entire heavy processing work to a remote brain, while maintaining control over the more primitive functions such as navigation and obstacle detection.

While the current release of Interactive C does not support Bluetooth, the soon-to-be-released Beta

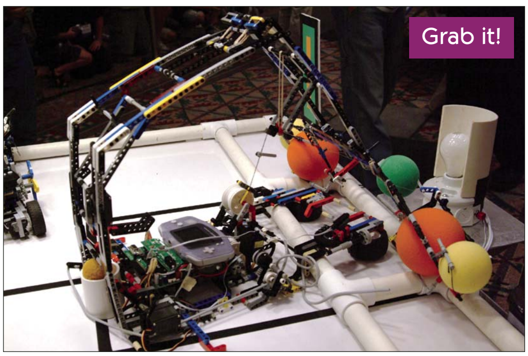


Everyone, take your starting positions ...



Get ready to fight!

7.0.l release will. Users will be able to connect their XBC through Bluetooth to a desktop and write code to use the Bluetooth chip as a serial communications port.



Grab it!

Kits and Equipment

There are several choices to make when purchasing the XBC. You can get just the controller, the controller with the camera, or the controller with the camera and GB. Each processor comes with the built in NiMH battery pack, serial cable, and an AC adapter.

Different kits are also available that include the XBC. The XBC Robot Starter Kit is the most popular (and the one being used for the NASA robotics course). It includes all the electronics, LEGO Technic pieces, and a CD with step-by-step instructions on how to build a working autonomous robot.

LEGO Technic allows the builder the ability to make mistakes that aren't permanent. All you have to do when you encounter a structural problem is take your robot apart and start over. That, of course, is half the fun!

What's to Come?

Short term — Botballers can expect another Botball season to use the XBC, and more home users and academic programs will incorporate it into their hobbies and experiments.

Long term — As middle school and high school students continue to study robotics and the wide range of practical applications it uses — science, technology, engineering, math, project management, and leadership — their ability in these areas when they reach college and beyond will be as highly developed as their Botball robots. **SV**

BASIC AND ADVANCED FEATURES

- Four motor ports
- Four servo ports
- Eight analog ports
- 16 digital ports
- One camera port
- Onboard power
- Back-EMF PID motor control
- Vision system with blob tracking

Omnidirectional Robot Vision

by Bryan Bergeron

Our eyes, optic nerves, and optic lobes constitute the most developed and information-dense human sensory system. Even so, there are other life forms with superior acuity, field-of-view, or spectral sensitivity. Articulated, single-lens eyes endow birds of prey with phenomenal visual acuity and field-of-view, and fixed, compound eyes provide many insects with omnidirectional vision that extends into the UV spectrum.

Robot vision has benefitted from biological inspiration, including this biodiversity. For example, the anatomy of robot imaging systems ranges from cameras with limited field-of-view mounted on pan-tilt mechanisms (see Figure 1), to fixed cameras combined with a fisheye lens, catadioptric omnidirectional mirror, or even lens clusters patterned after insect eyes [1]. Although the image processing capabilities of the most advanced robots can't yet compete with those of a common housefly, powerful CCD and frame grabber technologies are affordable enough for developers to add rudimentary vision capabilities to virtually any robot platform. This article explores omnidirectional robot vision options and describes the construction of an inexpensive omnidirectional mirror system for autonomous and tele-autonomous robots.

Robot Vision

A miniature, wireless pinhole camera, a 9V battery, and a dab of adhesive can transform a remote-controlled carpet roamer into a tele-autonomous robot with remote imaging capabilities. The technology that makes this possible is the CCD or Charge Coupled Device, such as the OV6620 Omnivision CCD in the popular CMUCam (see Figure 2). The CMUCam, which uses a glass lens instead of an inferior pinhole, captures 16.7 frames per second at 80 x 143 resolution.

Images are captured by a CCD and can be transmitted to a monitor and used as a visual navigation aid, processed with machine vision algorithms locally, or processed by algorithms executing on a PC. Local processing, such as the color tracking and servo control supported by the CMUCam2+ (see Figure 3), provides a low-cost introduction to autonomous robot vision. The PC option, while more complex and expensive, enables a robot to leverage processing power beyond what can be supported by onboard computers.

The typical field-of-view supported by small CCD cameras, such as the CMUCam, approximates the human field-of-view — about 40 degrees. As such, it's common to mount a small CCD camera on a tilt-pan head. This solution is straightforward, but it incurs a space, weight, and power penalty for

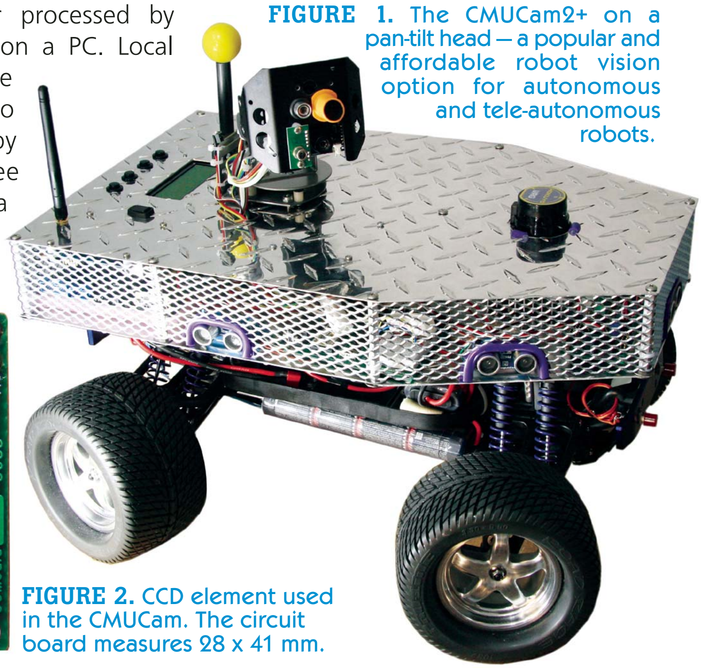


FIGURE 1. The CMUCam2+ on a pan-tilt head — a popular and affordable robot vision option for autonomous and tele-autonomous robots.

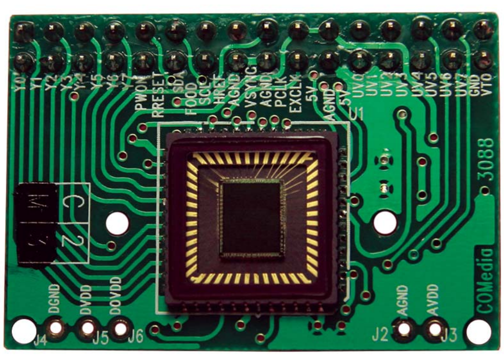


FIGURE 2. CCD element used in the CMUCam. The circuit board measures 28 x 41 mm.

Omnidirectional Robot Vision

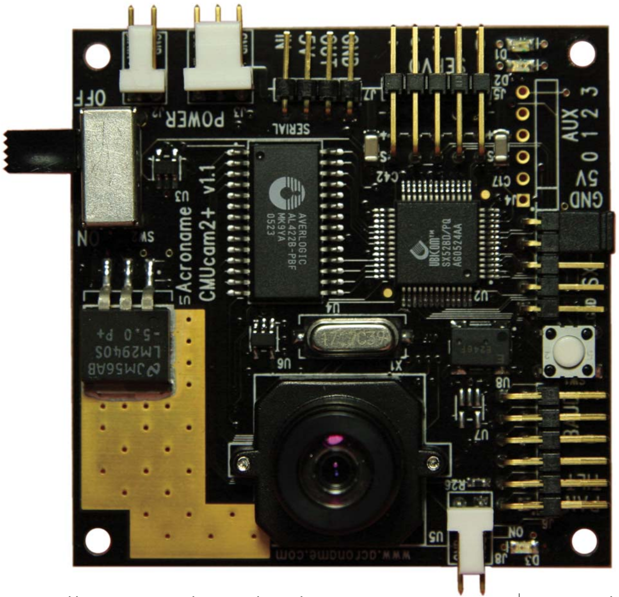


FIGURE 3. CMUCam2+ circuit board showing onboard image processing hardware.

the supporting structure, servos, and controller circuitry. Moreover, while vision systems with this configuration may be useful for relatively slow crawlers and carpet roamers, they are ill-suited for applications requiring speed and stealth. In addition, because of the physical limitations imposed by wiring and servo construction, tilt-pan heads typically provide significantly less than 360-degree horizontal coverage.

Consider the robot shown in Figure 1, which is an early version of a robot designed to play laser tag against humans. Despite a capable CMUCam 2+ and lightweight CrustCrawler tilt-pan head powered by a pair of high-velocity Airtronics 94358Z servos, the robot was easily defeated. The noise generated by the servos and obvious direction of the video camera were easily read by the opponents. The solution was to replace the mechanical, directional vision system with a system based on a non-mechanical omnidirectional design.

Omnidirectional Vision Technologies

Robot omnidirectional (360 degree horizontal) vision options include multiple fixed cameras, upward-pointing fisheye lenses, and fixed omnidirectional mirrors. Rotating mirrors, which are used successfully with IR laser rangefinders, are expensive and impractical for small robots.

Multiple Cameras

Multiple cameras, each assigned a particular field-of-view, offer the benefit of quiet operation and high resolution, at the expense of often considerable computational overhead. A workable option is to use an inexpensive multi-channel onboard frame grabber, such as the uCFG from Digital Creation Labs ($100), and four CCD cameras outfitted with wide angle lenses. The major challenge is how to switch between or merge the four video channels with the limited computational resources available on most robot platforms.

Fisheye Lenses

Fisheye lenses — wide-angle lenses on steroids — are compact, readily-available, and (for someone versed in optics) relatively easy to configure. Simply mount the lens on the camera or CCD assembly perpendicular to the ground and high enough above the robot body to avoid visual obstructions. The Nikon FC-E9 lens converter ($260), designed for the Nikon Coolpix, provides a field-of-view of 190 degrees. This and other fisheye lenses require appropriate mounting and optical adapters for use with a CMUCam or similar camera.

For low light conditions and greater resolution, a more capable fisheye lens, such as the AF DX Fisheye-Nikkor 10.5 mm f/2.8G ED ($540) is a better solution. The lens is designed for Nikon digital SLRs and can be combined with a mega pixel CCD to create a high-resolution, omnidirectional image capture system.

Readers interested in photography might consider purchasing a fisheye lens that can serve their photographic and robotics needs. However, for everyone else, the fisheye lens has several limitations that should be considered. Aside from the monetary investment, a limitation of the fisheye is that the majority of picture elements are typically wasted imaging the ceiling or sky. Obstacles, targets, and other interesting detail along the horizon are compressed along the periphery of the image. Furthermore, because the lens points upward, the robot body obstructs the view of floor conditions and obstacles near the robot that may be problematic.

Mirrors

Mirror-based omnidirectional imaging is increasingly popular among roboticists because it's a relatively inexpensive, lightweight, and powerful option. The basis of operation is simple enough — if you've ever used one of the convex mirrors commonly placed above pinch points in store isles, building corridors, or parking garages, you've experienced mirror-based omnidirectional vision first-hand. Construction is also straightforward — simply mount the mirror an appropriate distance above the lens of an upward-pointing camera.

The omnidirectional properties of a mirror-based system are a function of mirror geometry. Spherical, semi-spherical, parabaloid, hyperboloid, and conical geometries are the most popular in robotics (see Figure 4). Spherical and semi-spherical mirrors are useful when it's important to image the immediate vicinity of the robot in great detail, such as when a crawler must navigate unknown terrain. Conical mirrors, which

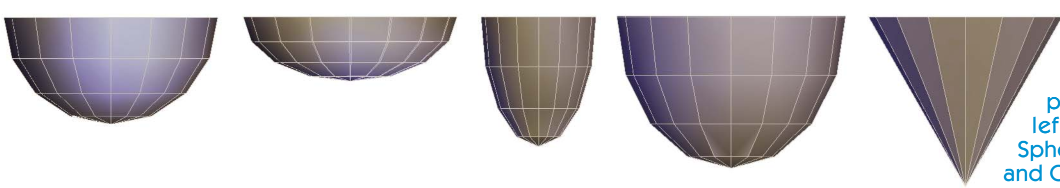


FIGURE 4. Spine view of popular mirror geometries, from left to right: Spherical; Semi-Spherical; Parabaloid; Hyperboloid; and Conical.

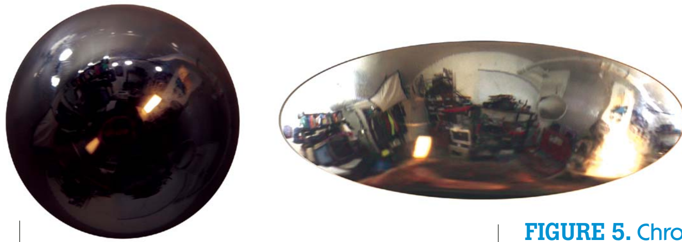


FIGURE 6. Original image captured from the 39 mm paraboloid mirror (left) and unwarped image reprojected onto a cylindrical surface (right).

provide virtually no close-range imagery and instead emphasize images on the horizon, are more appropriate for wheeled robots that operate on level terrain with obstacles on the horizon. Parabaloid mirrors devote pixels to both the immediate vicinity and the horizon, and can be used with virtually any robot platform.

Parabaloid mirrors (see Figure 5) produce images with less extreme variations in near to far image resolution than either conical or spherical mirrors. Even so, the raw image is much more distorted than the image produced by a typical semi-spherical security mirror. This isn't a problem if the goal is, for example, to identify the direction and distance to a target of a specified color. However, if the aim is to employ machine vision algorithms to identify recognizable features in the environment, then the image should first be unwarped and projected onto a virtual cylindrical surface, as shown in Figure 6.

There is a variety of unwarping software available for real-time robotics navigation and offline applications. The software used to create Figure 6 is a Photoshop Action that can be downloaded from **0-360.com**. The software is designed for their proprietary parabaloid mirror ($595), but it works reasonably well with any Parabaloid surface. For example, the chrome-plated mirror used in Figures 5 and 6 is sold on Amazon as a "silver chime egg" ($5/pair).

Regardless of the mirror geometry, the unwarping operation is a straightforward mapping process, as illustrated in the unwarping of the image from a conical mirror in Figure 7. The image reflected from the area near the apex of the cone is not only compressed original scene, but the image is distributed over relatively few pixels on the CCD. Conversely, the image reflected from the area near the base of the cone is stretched, and the pixel-to-image ratio is relatively high. As a result, horizontal resolution and image quality are best from the area near the base of a conical mirror. Note that the resolution along the vertical axis — from base to apex — is constant with a conical mirror. This is not true of parabolic and hyperbolic mirrors.

As noted earlier, mirror geometry defines the field-of-view. Furthermore, there can be significant variations in the field-of-view within a given mirror geometry. For example, Figure 8 illustrates the effect of conical mirror geometry on the resulting field-of-view. The squatter the cone, the more the mirror approximates a flat mirror, and the area surrounding the robot is imaged. Similarly, the more acute the cone angle, the more the field-of-vision encompasses the area at and above the horizon.

Beyond the basics of mirror geometry, there are several more variables related to the mirror and camera that should be considered. CCD resolution, camera lens aperture and field-of-view, mirror-lens distance, mirror reflectivity and size, mirror height, and robot platform size are all critical, interrelated variables. A first-surface glass mirror will reflect more light than a mirror of stainless steel, while the reflectivity of a chrome-plated aluminum mirror is somewhere between the two. As a result, an omnidirectional image system built around a stainless steel mirror will require greater ambient light levels.

A camera lens with a shorter focal length will allow a closer mirror-lens distance, which makes for a more compact, sturdy camera system. However, a wide robot body generally requires a greater camera-mirror distance to show the area in the vicinity of a robot, especially with a spherical or semi-spherical mirror.

The basic photographic principles of minimal working distance and depth-of-field apply to imaging the mirror surface. Depth-of-field, which

FIGURE 5. Chrome-plated 39 mm parabaloid mirror mounted in a two-inch Plexiglas tube.

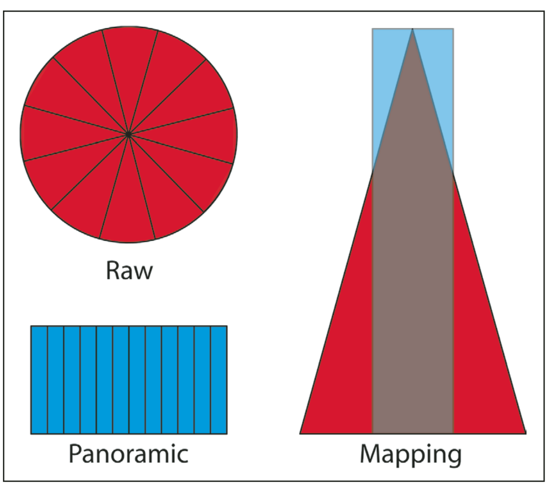


FIGURE 7. Unwarping an image from a conical mirror (top left) can be visualized as mapping raw triangular slices onto rectangular slices on a cylindrical panoramic surface.

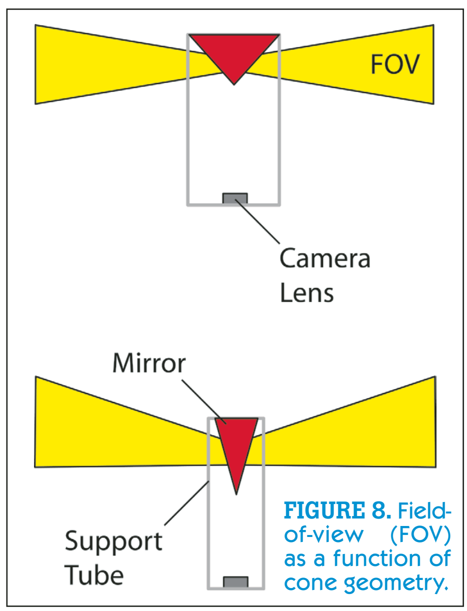


FIGURE 8. Field-of-view (FOV) as a function of cone geometry.

FIGURE 9. Omnidirectional cone imaging system installed on the robot.

should be sufficient to capture the image from the full surface of the mirror, can be increased by stepping down the lens aperture. Unfortunately, the CMUCam and CMUCam2+ have fixed aperture lenses. However, unlike a simple pinhole camera, working distance (close focus) can be adjusted by rotating the lens.

Conical Mirror Omnidirectional Vision System

Readers with a miniature CCD camera can add omnidirectional vision capabilities to their robot by creating a conical mirror assembly (see Figure 9) for about $10 in supplies — a tennis ball container, plastic funnel, and sheet of Duralar — and a few hours at the bench. The following discussion assumes a CMUCam2+, but cameras such as the CMUCam or a miniature pinhole camera work with minor modifications.

FIGURE 10. Raw materials for a lightweight cone mirror — silver Duralar and a 65 mm diameter plastic funnel.

The raw materials required for the cone mirror are a sheet of silver Duralar and a small plastic funnel. Duralar or comparable paper-backed mirrored surface can be found at most art supply stores, and plastic funnels of various sizes and shapes are available at cooking supply and hardware stores. Look for a funnel with a 65 mm diameter rim — the diameter of a tennis ball. If you can't find one this small, you can cut down a larger funnel.

Prepare the funnel by removing the pouring spout from the funnel and, using medium-grit sandpaper, remove the small ribs, mold lines, or other imperfections on the surface of the funnel. Clean the funnel surface and set it aside.

The Duralar has to be glued or taped to the funnel, creating a silver cone. Using the template available on the *SERVO* website (**www.servomagazine.com**; see Figure 11), print out the cone overlay on plain paper and cut out the pattern. Try it out for size on the prepared funnel. Adjust the print size and wedge angle so that the cone comes to a clean point with about 1/4" overlap at the seam. When you're satisfied with the fit, tape the paper pattern to the back of the Duralar and cut to size. Be careful not to scratch the Duralar surface during handling.

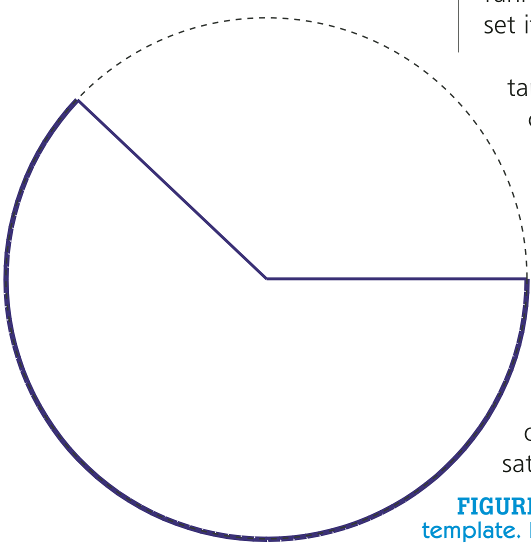


FIGURE 11. A 125 mm diameter Duralar template. Duralar limits are in blue.

Apply a thin coat of rubber adhesive to a few points on the funnel and corresponding points on the back of the Duralar. Mate the points after five minutes. Use the minimum amount of glue possible to avoid staining or crinkling the Duralar. It's a good idea to test the effect of the adhesive on a piece of scrap Duralar before gluing. An alternative approach is to use double-sided tape. Whatever method you use, make the overlap area as smooth as possible. If you're handy with a blade, do away with the overlap altogether and butt the edges of the Duralar prior to gluing.

Create a 70 mm disc out of 3/4" (20 mm) packing foam or other low-density spacer material and glue it to the base of the cone mirror. The purpose of the disc is to push the mirror from the tube distortion near the cap end of the tennis ball tube (see Figure 9). Set the mirror assembly aside to dry.

The next step is to mount the camera and create a supporting structure for the mirror. A CD-ROM happens to fit the CMUCam2+ lens snugly, and mounting the camera board on the disc requires only four quick holes and 1/4" standoff hardware. With camera mounted, you'll need a clear, colorless support tube. A clear tennis ball container will accommodate the funnel and is lightweight. Using a sharp blade, cut the pressurized container cleanly about 115 mm from the cap end. Keep the peel-off lid intact. The metal lid helps maintain the rigidity of the tube.

Place the mirror and tube assembly over the camera lens. Using the constant streaming function of the CMUCam2+, adjust the focus so that most of the mirror is in focus. You should see something like the image in

Figure 12. Objects will be distorted and stretched toward the periphery of the image.

Because the CCD element is rectangular, there is an unavoidable waste of pixels if the entire mirror is imaged. The field-of-view in Figure 12 sacrifices part of the mirror surface in exchange for higher resolution image on the area of the mirror that is imaged. To image more of the mirror imaged, cut the support tube at 120 mm or use thinner backing material. Secure the base of the tube to the CD-ROM or other mount. The aluminum base of a lamp assembly is used for the lower attachment in Figure 9. A second tennis container cap bolted or glued to a CD-ROM also makes a sturdy, lightweight base.

Variations

Components other than a CMUCam2+, 67 mm funnel, and 20 mm foam backing for the mirror will probably require a different tube length. Fortunately, the real-time imaging available with a CCD camera supports interactive experimentation. Feel free to try different materials, mirror geometries, and support structures. Christmas tree baubles and chrome-plated cabinet pulls (see Figure 13) provide an inexpensive and workable introduction to mirror-based omnidirectional robotic vision. Experiment with different shapes, finishes, and materials until you get a feel for the features associated with each.

At only 33 g, the Duralar cone assembly is light enough to be used with virtually any robot base. The downside of Duralar is lower reflectivity relative to chrome or silvered glass. Chrome-plated metal, while less reflective than mirrored glass, can withstand the hazards of mobile robot activity. There is a modest weight penalty, however. For example, the 108 g chrome egg shown in Figure 5 requires relatively heavy Plexiglas tubing for support; 3" o.d., 0.1" thick Plexiglas tubing incurs a weight penalty of 19 g per inch, while 2" o.d. tubing is a little less burdensome at 13 g per inch.

An advantage of rigid Plexiglas over thin-walled plastic container is more stable camera-mirror placement. Plexiglas tubing is also more likely to withstand inevitable crashes. Borosilicate glass tubes — available through science supply houses — provide superior optical properties, although they are less resilient and heavier than Plexiglas.

FIGURE 12. Original image from CMUCam2+ and Duralar cone. Note target in red shirt, about six feet from the robot. The Duralar seam is at eight o'clock.

My current omnidirectional robot vision system is based on the CMUCam2+, a 2" o.d. borosilicate tube, and a chrome-plated aluminum cone mirror. The mirror, which is sold as a motorcycle bar end ($40/pair), is perfect for imaging human targets six to 20 feet from the robot base.

The real fun begins when you integrate the omnidirectional vision system with your autonomous or tele-autonomous robot. The conical imaging system works as-is with the CMUCam2+ color tracking software. Instead of directing the tilt/pan head, use the servo signals to drive the drive servos or H-bridge, depending on your robot design. Full documentation on the CMUCam2+ color tracking routines is available from Seattle Robotics (see Resources sidebar).

A tele-autonomous robot with a wireless pinhole camera and conical mirror is also a reasonable experimental system for a tele-autonomous robot. After a few minutes of working with the raw omnidirectional view, most readers will find the distorted view easy to interpret without unwarping software.

From Here

Readers with deep pockets might consider replacing the affordable but limited CMUCam 2+ with a mega pixel, large aperture video camera and a specially fabricated metal or first-surface glass mirror. As a point of reference, Neovision sells the H3S — a 200 g, 28 mm hyperbolic stainless steel mirror for about 850 Euros. Seiwapro offers a variety of similarly priced precision spherical and hyperbolic silvered glass mirrors with Sony camera mounts.

The H3S and Seiwapro mirrors are popular among robot vision researchers because the mirror surface equations are published. For example, Neovision lists the H3S surface equation as:

$$\frac{z^2}{789{,}3274} - \frac{x^2 + y^2}{789{,}3274} = 1$$

FIGURE 13. A chrome-plated cabinet pull makes an inexpensive, high-reflectivity semi-spherical mirror.

REFERENCES

• [1] Franceschini, N., Pichon, J., and C. Blanes, *From insect vision to robot vision.* 1992. Philosophical Transactions of the Royal Society of London B(337): p. 283-94.

• [2] Zivkovic, Z. and O. Booij, *How did we build our hyperbolic mirror omnidirectional camera — practical issue and basic geometry.* 2005, University of Amsterdam, Intelligent Autonomous Systems, IAS-UVA-05-04.

Omnidirectional Robot Vision

RESOURCES

- *Seattle Robotics*
  www.seattlerobotics.com
  CMUCam and wide angle lenses

- *Acroname*
  www.acroname.com
  CMUCam2+

- *LP Music Collection*
  wwww.lpmusic.com
  Silver Chime Eggs; LPM324; Garfield NJ 07026. Also available through **Amazon.com**

- *JDA Custom*
  www.jdacustom.com
  Chrome-plated aluminum cone bar ends

- *0-360.com*
  http://0-360.com
  Photo Unwrapping Action for Photoshop and Photoshop Elements

- Precision parabolic/hyperbolic mirrors and camera assemblies:
  – *Neovision Industrial Vision Systems*
  www.neovision.cz
  – *0-360.com*
  http://0-360.com
  – *Kaidan, Inc.*
  www.kaidan.com
  360 OneVR
  – *Neuronics*
  www.neuronics.ch
  V-Cam360,
  Panorama Eye, Seiwapro Co., LTD.
  www.accowle.com/english/index.html

- Digital Creation Labs, Inc.
  www.digitalcreationlabs.com/uCFG.htm
  uCFG Microcontroller Frame Grabber

- eStreetPlatics
  eStreetPlastics.com
  2" and 3" Plexiglas Tubes

Unwarping software written for HS3 hyperbolic surface, for example, can be shared among researchers using the mirror. Published surface equations can also be used to create a virtual mirror t within a 3D rendering package, such as AutoCAD, for testing room coverage at different mirror heights and mirror-camera distances. Of course, the surface equations for a conical or spherical mirror are easily defined.

Readers interested in machine vision can experiment with the Photoshop Actions software discussed earlier. Owners of Matlab can explore the listing provided by the Intelligent Autonomous Systems of University of Amsterdam [2]. A wealth of unwarping software and omnidirectional imaging systems are described on "The Page of Omnidirectional Vision," which is hosted by the GRASP Laboratory at the University of Pennsylvania.

Furthermore, robotic omnidirectional vision isn't an either-or proposition. It's a simple matter to add an omnidirectional mirror and inexpensive pinhole camera to enhance an existing robot design based on a normal lens and tilt/pan head. The omnidirectional camera can act as an early warning system of sorts, giving you time to swing the tilt/pan head around to a potential threat or obstacle. Whatever your final configuration, once you experience omnidirectional vision, you'll find it difficult to go back to the visual confines of a standard imaging system. **SV**

FURTHER READING

- Horn, B., *Robot Vision*. 1986, Cambridge: MIT Press.

- Shih-Schon, L. and R. Bajcsy, *Single-View-Point Omnidirectional Catadioptric Cone Mirror Imager*. IEEE Transactions on Pattern Analysis and Machine Intelligence, 2006. 28(5): p. 840-5.

- Center for Machine Perception, Czech Technical University Prague. **cmp.felk.cvut.cz/demos/OmnidirectionalVision.html**

- Chahl, J. and M. Srinivasan, *Reflective surfaces for panoramic imaging*. Applied Optics, 1997. 36(31): p. 8275-85.

- The Page of Omnidirectional Vision. **www.cis.upenn.edu/~kostas/omni.html**

Real Time Operating Systems TO THE RESCUE

A Review of FreeRTOS.org

by Phil Davis

A couple of months ago, I wrote an article for the Appetizer section of *SERVO* and there I talked at length about the need for better and more sophisticated tools when it comes to architecting your robot program. Most of us take our BASIC Stamps or even Atmel Mega32s and hope to crank out some 'basic' or 'C' code with the idea of breathing Artificial Life into our bots. It's true! We have these grandiose ideas about the end state of our machine: it will avoid all obstacles, climb stairs, obey voice commands and, of course, recognize all by facial image.

The desire to have all of these features in our bots is admirable, but like anything else, we need the tools to achieve this.

You see, the 'big guys' building the mainframe computers and the super mini computers have known this for a long time. They started out just like us, in that they would write code directly on top of the hardware, but over time, they realized that to do more they needed a better tool set underlying the code they wrote. So, primitive operating systems were born. Of course, over the years these have evolved to become very sophisticated, like the well-known UNIX or LINUX operating systems or the ubiquitous Microsoft Windows.

There is a reason why these OSs exist and why they continue to evolve; because they lift our programming above the hardware and provide a level of abstraction for us to program in. Consequently, we can write more scalable, complex, and 'able' programs.

So, it is with all this in mind that I wanted to talk further about FreeRTOS.org — a small, tight, and fast Real Time Operating System from **www.FreeRTOS.org**. You may have noticed that part of the name has the word 'free,' yes; this super OS is, in fact, free.

Let's dig into this OS in depth through the presentation of a hypothetical example:

<u>The Problem</u>

Consider a simple robot that is designed to move around a space, avoiding obstacles that are placed randomly in the same arena. The robot is connected via a radio link to a base station which can update the control parameters used by the robot (maximum speed, etc.), and ask the robot to send it status information.

The software required to operate this robot has several characteristics. For example, controlling the speed and direction of the motors requires periodic processing at known intervals, while responding to collision avoidance sensors and radio communications requires a fast response to events that can occur at any time.

How might the software for this system be designed?

<u>The Super Loop Solution</u>

The super loop is the most basic potential solution and is demonstrated in Listing 1. In this solution, the program is split into functional blocks — each of which is allocated to a subroutine. The microcontroller simply loops around continuously, processing each subroutine in turn.

This type of design can work for small systems, and indeed many small embedded software programs are written in exactly this manner.

There are, however, several shortcomings. In particular, the variation in the time it takes to execute one cycle of the loop can be the source of many problems. This variation occurs when different paths are taken through the subroutines. As a consequence:

• The time taken between an input changing and the software reacting to the change will vary. Worse still, the variation range will change if the software is modified. In the worst case, a momentary change in a sensor input may go unseen.

• Code cannot rely on a fixed execution period. Many algorithms — such as the digital filters that are often used in motor control applications — will rely on a fixed execution period.

```
main()
{
    InitializeHardware();

    /* Loop forever. */
    for( ;; )
    {
        ControlMotors();
        ProcessCollisionSensors();
        ProcessRadioComms();
    }
}
```

LISTING 1. A basic super loop.

```
main()
{
    InitializeHardware();

    /* Loop forever. */
    for( ;; )
    {
        ControlMotors();
        ProcessCollisionSensors();
        ProcessRadioComms();
        ProcessCollisionSensors();
    }
}
```

LISTING 2. Calling a subroutine twice within the same loop.

• Subroutines that handle events will be executed whether or not the event occurred — wasting processing time and therefore power.

These all mean the design will not scale well should the scope of the application be increased, but simple modifications can be introduced to alleviate these issues. To give some examples:

• Interrupts (an automatic program jump to a special subroutine that is triggered by a change in an input state) can be used to ensure momentary changes in inputs are not missed.

• A timer can be used to make the loop execute with a fixed frequency.

• The order and frequency with which each subroutine is executed can be changed. For example, Listing 2 shows ProcessCollisionSensors() being called twice within the loop. Executing ProcessCollisionSensors() more frequently in this manner might prevent it from missing a momentary input.

While these solutions are simple and sufficient for small systems, they will ultimately suffer from the same shortcomings when used within a more complex or expanding application. *A more scalable solution would permit the timing and sequencing information to be abstracted out of the application software* — which is where the use of a real time kernel such as FreeRTOS.org can assist.

An Alternative Approach — Using FreeRTOS.org

As an alternative solution, each subroutine presented in Listing 1 is changed into a mini program in its own right. Each mini program is structured so that it never exits. For example, ProcessRadioComms() might have taken the form depicted in Listing 3 when originally written as a subroutine, but be converted to the form depicted in Listing 4 once rewritten as mini program.

```
void ProcessRadioComms( ...... )
{
    /* Has any data been received from the radio link? */
    if ( IsDataAvailable() )
    {
        /* Data is available, so process it. */
        DecodeReceivedData();
        ProcessDecodedMessage();
    }
}
```

LISTING 3. vProcessRadio Comms() organized as a subroutine.

```
/* What was a subroutine is now a program that never exits. */
void RadioCommsTask( ...... )
{
    /* Loop forever. */
    for( ;; )
    {
        /* Has any data been received from the radio link? */
        if( IsDataAvailable() )
        {
            /* Data is available, so process it. */
            DecodeReceivedData();
            ProcessDecodedMessage();
        }
    }
}
```

LISTING 4. ProcessRadio Comms() reorganized as a mini program.

The application functionality is now split into a set of independent mini programs. To achieve all the functionality at once, each mini program will have to execute simultaneously — which is what FreeRTOS.org allows you to do. Each mini program is called a task, and executes under the control of the FreeRTOS.org kernel as in Listing 5.

```
int main( void )
{
    InitializeHardware();
    /* Create each task using the functions provided
    by the FreeRTOS.org kernel. */
    vTaskCreate( ControlMotorsTask );
    vTaskCreate( RadioCommsTask );
    vTaskCreate( CollisionSensorsTask );

    /* Once all the tasks have been created, the FreeRTOS.org
    kernel can be started. */
    vTaskStartScheduler();

    /* Once the scheduler has been started the tasks will be
    executing, so the program will never reach here. */
}
```

LISTING 5. Creating the tasks and starting the real time kernel.

A standard microcontroller is only capable of executing a single program at any one time. The separate tasks are therefore not really executing simultaneously. The FreeRTOS.org kernel provides the illusion of simultaneous execution by rapidly switching each task on to and off of the processor.

Figure 1 demonstrates this concept. In this diagram, time moves from left to right, with the task that is executing at any given time being highlighted by the color of the line. For example, the RadioCommsTask is executing between times t1 and t2, a so-called time slice.

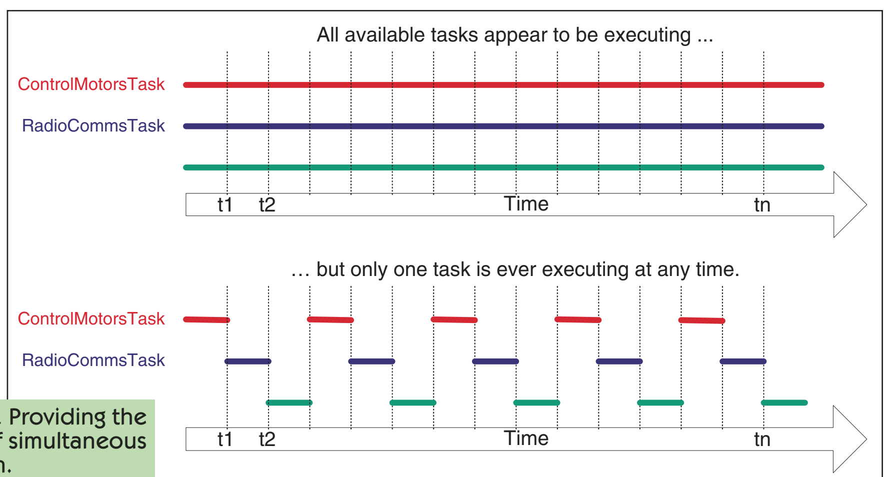


FIGURE 1. Providing the illusion of simultaneous execution.

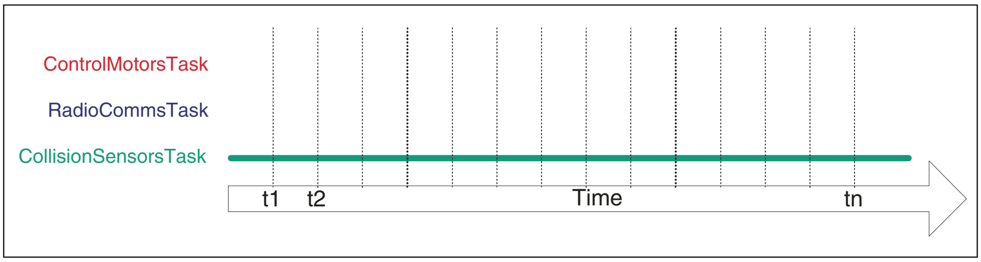


FIGURE 2. The highest priority task is starving the lower priority tasks of processing time.

LISTING 6. Assigning a priority to each task as it is created.

```
int main( void )
{
    InitializeHardware();

    /* This time a priority is assigned to each task
    as it is created. */
    vTaskCreate( ControlMotorsTask, MediumPriority );
    vTaskCreate( RadioCommsTask, LowPriority );
    vTaskCreate( CollisionSensorsTask, HighPriority );

    vTaskStartScheduler();
}
```

Prioritization

So far, organizing our program as a set of separate tasks has allowed a higher level of abstraction to be used in the program design.

• Partitioning the software into a set of separate tasks allows the software to be more modular with fewer interdependencies.

• Time slicing has made the execution a degree more predictable — for example, the CollisionSensorsTask is guaranteed to execute every third time slice, no matter what the other tasks are doing.

However, we have not yet obtained the timing and sequencing abstraction we set out to achieve. We must first introduce *prioritization*.

Each task is assigned a priority. The FreeRTOS.org kernel will not execute a task if another task has a higher priority and is also able to execute. In other words, a low priority task will never prevent a higher priority task from executing.

The priority assigned to a task becomes an important design decision and directly affects the execution pattern of the tasks — but the execution pattern is now the responsibility of the FreeRTOS.org kernel. It has been abstracted away from the application code itself and therefore, to some extent, the application designer. This results in a simplified and more scalable software design.

FreeRTOS.org does not place any practical limits on the number of different priorities that can be used within an application, or the number of tasks that can share the same priority. This makes it a very flexible system. Figure 1 depicts the execution pattern that would be obtained if each task were assigned the same priority.

The assignment of priorities to tasks will be dependent on the system requirements, input/output characteristics, and hardware architecture. For our example, let us make some assumptions about the behavior we require:

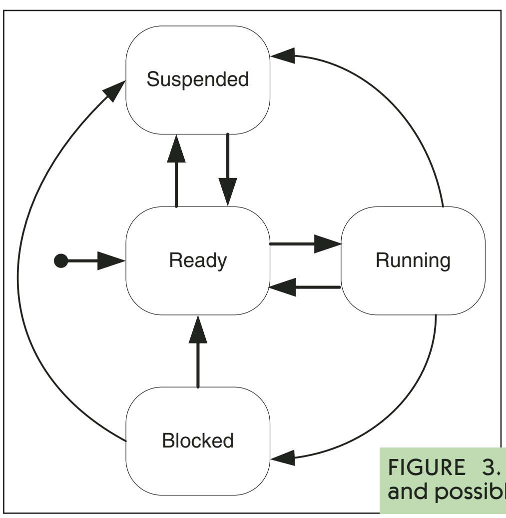


FIGURE 3. Task states and possible transitions.

1. The radio communications task must respond sufficiently fast to ensure the buffers used to store received data do not become full, but the buffers are quite large and communications events occur sporadically.

2. The collision sensors task must react very quickly to any change in input conditions as a collision could be imminent.

3. The motor control task requires periodic processing at an accurate and constant frequency.

Given these assumptions, it would seem prudent to assign priorities as depicted in Listing 6.

So far, I have only hinted that a task can exist in more than one state: *"The FreeRTOS.org kernel will not execute a task if another task has a higher priority and is also able to execute."* Why would we want to make a task unable to execute?

If a task was always able to execute, then only the highest priority task would ever run. In our case, the CollisionSensorsTask would execute permanently to the detriment of the ControlMotorsTask and RadioComms Task (Figure 2).

FreeRTOS.org allows a task to exist in one of the four states — demonstrated by Figure 3.

So far, we have seen the Running state (when the task is actually executing) and the Ready state (where the task is able to execute, but is not currently executing). For our application to execute efficiently, we need to introduce the Blocked state. (See the FreeRTOS.org website for information on the Suspended state.)

While in the Blocked state, a task is waiting for something to happen. That something could be:

• Waiting for a fixed time period to elapse. The FreeRTOS.org function vTaskDelay() can be used for this purpose.

• Waiting for an absolute time. The FreeRTOS.org function vTaskDelayUntil() can be used in this case.

• Waiting for a queue or semaphore

event. Queues and semaphores are mechanisms that permit communication with a task.

By way of demonstration, let's revisit our task RadioCommsTask, this time placing the task into the Blocked state when there is no processing to perform.

In Listing 7, the task indicates that it wants to wait for a period of MAX_DELAY for data to arrive on the queue named RadioQueue. If no data is available, it will enter the Blocked state. When the task leaves the Blocked state, the received data will have been placed in the ReceivedData buffer.

An interrupt routine is used to automatically place data into RadioQueue as it arrives. This is all the interrupt has to do, so it is very short. By the time the interrupt has completed, RadioCommsTask will have transitioned from the Blocked state to the Ready state — and will execute immediately if no tasks of higher priority are able to do so (Listing 7).

```
void RadioCommsTask( ...... )
{
Buffer ReceivedData;

    /* Loop forever. */
    for( ;; )
    {
        /* Read received radio data from a queue. The task will
        enter the Blocked state if no data is available. */
        if( xQueueReceive( RadioQueue, ReceivedData, MAX_DELAY ) )
        {
            DecodeReceivedData();
            ProcessDecodedMessage();
        }
    }
}
```

LISTING 7. RadioCommsTask() transitioning to the Blocked state when no processing is necessary.

```
void ControlMotorsTask( ...... )
{
Buffer ReceivedData;

    /* Loop forever. */
    for( ;; )
    {
        /* Delay until it is time for the next control cycle. */
        vTaskDelayUntil( LastExecutionTime + 20 );

        /* When execution reaches here the task will have transitioned from
        the Blocked state first to the Ready and then the Running state
        because the time at which we asked to unblock has been reached. */
        PerformMotorControlFunction();
    }
}
```

LISTING 8. ControlMotorsTask() transitioning to the Blocked state when no processing is necessary.

Modifying ControlMotorsTask so it blocks too results in a very simple structure. It simply blocks until an absolute time is reached — the time at which it should start its next execution cycle. See the comments within Listing 8 for details.

Ideally, the CollisionSensorsTask will take a similar structure to Listing 7 — blocking waiting for a sensor input to change. If the hardware does not permit the sensor inputs to generate interrupts, it can instead take the structure of Listing 8, but using a very short delay period to ensure it scans its inputs frequently.

Results

So how might our program now execute? Figure 4 demonstrates a possible execution pattern. In Figure 4, 13 points in time are highlighted and labeled t1 to t13:

- Between times t1 and t2, ControlMotorsTask executes one complete cycle. No other tasks execute within the same time period. Once it has completed one cycle, it enters the Blocked state again to wait for the time at which it should once again execute.

- At time t3, some data is received from the radio link — causing the RadioCommsTask to leave the blocked state so that it can process the data. At t4, all the data is processed and there is nothing for RadioCommsTask to do, so it blocks.

So far, the execution pattern has been simple. Only one task has ever wanted to be executing at any given time. What happens when this is not the case?

- At time t5, more radio data arrives — causing RadioCommsTask to leave the Blocked state. It starts to process the data, but this time ...

- ... at time t6, ControlMotorsTask wants to start its next execution cycle. Now both ControlMotorsTask and RadioCommsTask want to execute. ControlMotorsTask has the higher priority, so *preempts* RadioCommsTask and starts executing immediately.

- ControlMotorsTask eventually completes the processing necessary for that control cycle and again enters the Blocked state — t7. RadioCommsTask is once again the highest priority task that wants to execute and completes its processing before it too blocks at t8.

This demonstrates how the

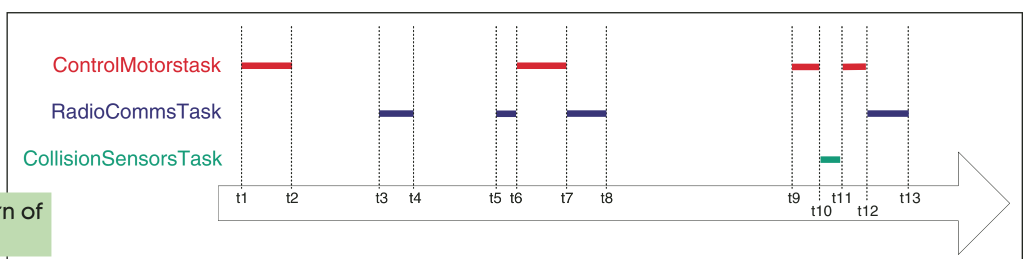


FIGURE 4. Sample execution pattern of blocking prioritized tasks.

FreeRTOS.org kernel controls the execution pattern to guarantee the timing of the higher priority task. The lower priority RadioCommsTask was forced to wait until ControlMotorsTask had Blocked. ControlMotorsTask can itself be forced to wait for CollisionSensorsTask, as shown between times t9 and t13.

Figure 4 highlights one other consequence of this scheme. For large periods of time, there are not tasks that want to execute — they are all in the Blocked state. During these periods, the FreeRTOS.org kernel can be configured to place the microcontroller into a power down (sleeping) state, saving valuable battery power.

Getting Started With FreeRTOS.org

FreeRTOS.org is provided as a set of C source files that can be downloaded from **www.FreeRTOS.org** for inclusion in your software. These source files define a rich set of subroutines — some of which we have used in this example: vTaskCreate(), vTaskDelayUntil(), and xQueueReceive(). These and many others are documented on the FreeRTOS.org website.

Each type of microcontroller supported by FreeRTOS.org (there are many) comes with an example application. An easy way to start with FreeRTOS.org is to first experiment with one of these examples, then modify the example to take out the example code and replace it with your application code. This way, you start with something that is already working. You may want to consider additional tools such as the GNU GCC compiler for C which is also available free-of-charge.

More information, tutorials, and source code can be found at **www.FreeRTOS.org**.

One of the great things about FreeRTOS.org is that it's free, with support being provided by users through a support forum. However, for those of you who may be interested in incorporating FreeRTOS.org into your own commercial product, Wittenstein is offering a fully supported version along with licensing: **www.highintegrity systems.com/freertospro.html**

Conclusion

Using FreeRTOS.org enabled us to organize our application as a set of prioritized separate tasks. This provided a greater level of abstraction and removed the necessity for the application to directly concern itself with sequencing and timing. Prioritization provided a degree of determinism in the execution pattern of the software components to which we assigned a high priority.

If I can find the time, in future articles, I would like to give some practical examples of simple programs performing some well-known functions such as obstacle avoidance or Mini Sumo wrestling. So, stay tuned. **SV**

FreeRTOS™ and FreeRTOS.org™ are trademarks of Richard Barry.

How to

Convert Cordless Drill Motors for Use in Robot Drives

by Peter Smith

Many robots use small DC motors and a gearbox to reduce the RPM and to increase torque. One popular way of doing this is to use the combined gearbox and motor from a cordless drill. These typically have a 12V-18V motor attached to a 36:1 planetary gearbox.

There are two main sources for suitable drills. Harbor Freight (**www.harborfreight.com**) and Homier (**www.homir.com**). Harbor Freights Model 91396 and Homier 02899 are suitable. Avoid drills that have "hammer" features and remember, the cheaper the better. It should not be necessary to pay more than about $25 per drill. Various voltages are available but the drills tend to use standard 550-sized motors, so even if the voltage of the one you get is not really suitable, the motor can be replaced by another more suited to your application.

PHOTO 1

Output speed is usually about 500 RPM at the rated voltage. They are powerful enough for a pair to run a 12 lb combat robot (the robots that took the first three places in the 12 lb class in the 2006 RFL National Championship all used cordless drill parts).

The drill used in this article is the Harbor Freight 91396 (see Photo 1) set which came with an 18V battery, a small flashlight, plus some assorted drill bits and screwdriver bits. The first thing to do is charge the battery per the manufacturers instructions.

You'll need to remove the chuck from the drill (see Photo 2) before disassembling the rest. The chuck is locked in place by a small, left-hand threaded, screw inside the chuck itself (see Photo 3). If you are really lucky, you can remove this Phillips #2 screw using a screwdriver (remember to turn clockwise to loosen a left-hand thread), but they are usually too tight.

There are two methods which will work to remove it. The first is to use another drill to start drilling out the screw. The heat and torque applied by the drill bit will loosen the screw and it will come out rather than be bored out by the drill. The downside of this approach is that you need a second drill and that the screw itself will be damaged. The second method — and the one that I use — is to get an "impact driver." The driver must be able to loosen or tighten screws (many of the cheaper ones only loosen right-hand thread screws and will only make the left-hand threaded screw on the drill even tighter!) McMaster Carr part 5610A2 (**www.mcmaster.com**) will do the job. I needed to use a 1/4" socket and an extension piece to get it to be

PHOTO 2

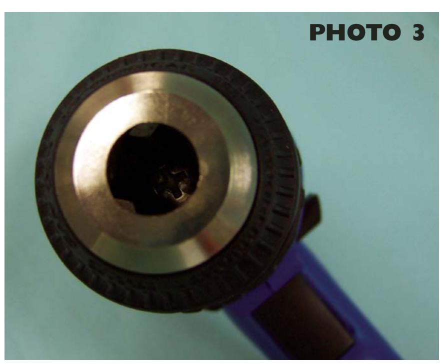


PHOTO 3


PHOTO 4

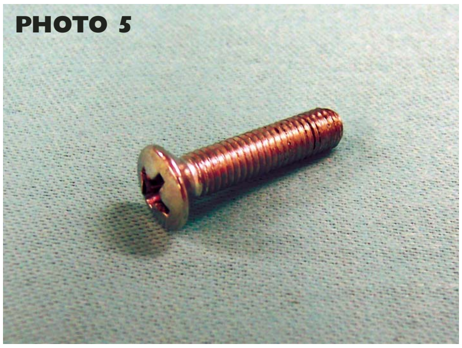


PHOTO 5


PHOTO 6

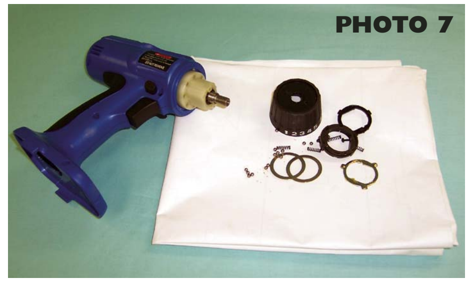


PHOTO 7

able to reach the screw (see Photo 4.)

Set the driver to turn clockwise and with the chuck held securely in a vice, give the back of the driver a sharp tap (or two) with a hammer and the screw will be loose enough to easily remove. Keep the screw (see Photo 5) for later use.

The chuck is threaded onto the gearbox using a conventional right-hand thread. This will usually be too tight to remove by hand, but there is an easy way to remove it. Fit the newly charged battery into the drill and place a large hex key (see Photo 6) in the chuck. Set the drill in reverse, spin it up, and then allow the end of the hex key to strike a solid object (like a vice or workbench). The shock will loosen the chuck and it will come off easily.

I would advise the use of safety glasses and an absence of spectators for the above procedure and don't do it next to anything breakable!

There are two screws on the front face of the drill under where the chuck was attached. Remove these screws and then the adjustable torque mechanism can be removed (see Photo 7). The device varies on the make and model of drill, but all the parts can be discarded. Next, remove the screws that hold the two halves of the drill together and lift off the top half (see Photo 8). The motor and gearbox (see Photo 9) can then be lifted out of the other half of the case. The wires can be cut and everything else (apart from that left-hand screw) can be discarded.

There are eight openings around the front face of the gearbox (see Photo 10). These are used by the torque adjustment mechanism and we will now use them to lock the outer ring of the gearbox. The outer ring (see Photo 11) has a series of bumps around one end. If you look into the holes at the end of the gearbox and slowly rotate the shaft, you can see them pass by.

To allow the gearbox to transmit power from the motor to the output shaft, it is necessary to stop the outer ring from moving. This is done by adding 10-24 by 3/16" setscrews (see Photo 12) into every second opening (see Photo 13). The setscrews self-tap into the holes and you should ensure that they engage the gaps between the bumps on the outer ring. Do not over-tighten the screws as you are likely to distort the gearbox and cause premature wear or failure. All that is required is that the outer ring is stopped from rotating.

The motor/gearbox is now ready for use in your robot. It can easily be mounted by cutting a hole in the side wall of you chassis that matches the front block of the gearbox and a support that fits around the motor itself (see Photo 14). You can get wheels that fit directly onto the shafts from **www.cncbotparts.com** (look under Handihubs) and are secured by the left-hand threaded screw. **SV**

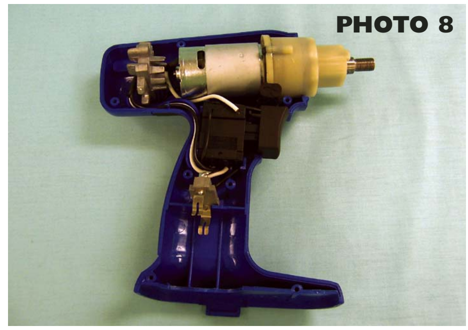


PHOTO 8

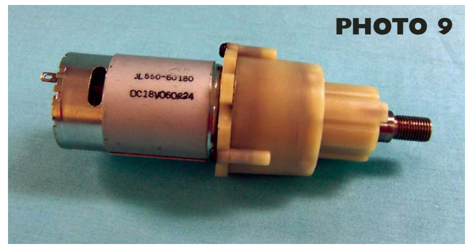


PHOTO 9

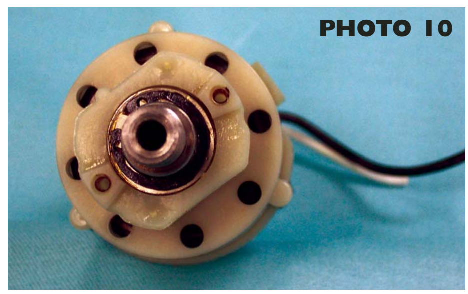


PHOTO 10

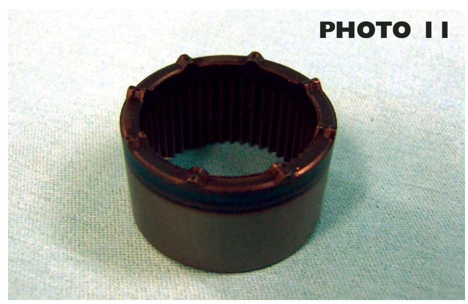


PHOTO 11

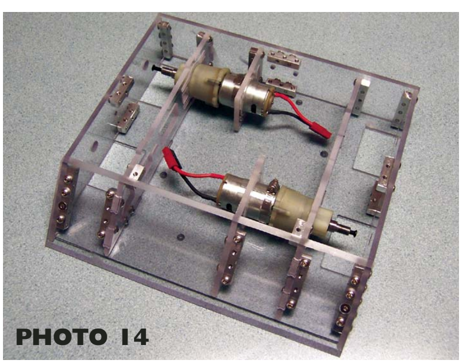


PHOTO 14


PHOTO 13

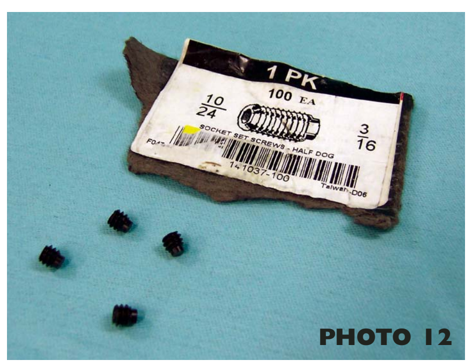


PHOTO 12

by Dave Calkins

ROBOGAMES PREP:

Androids!

Let's face it. When people think robots, they think androids. Even we jaded robot builders who have homes, offices, and garages filled with motors, wheels, platforms, microchips, and sensors — even we want an android for a robot far more than a wheeled platform. It's just ... cooler.

Well camper, if it's an android you want, get off your duff and build one! Or at least buy one and get modding. There are now tens of thousands of humanoid robots walking around this planet, and you don't need to have Honda's budget to afford one. You now can have a working humanoid robot for under a thousand bucks. Heck, my first two-wheeled sumo cost as much as a low-end android costs these days!

If you're patient and willing to fail a few times before you succeed, you can build any robot. All robot builders fail a few times. If you're patient, have built a few servo-based robots, are willing to fail a lot, and want to really impress every person you meet, you're ready to move up to androids.

But before you start, you've got a few decisions to make:

- First, are you going to buy an android, or make your own?
- Second, in which events will you compete?

Let's start with the second decision. That may seem odd, but it's very important. You need to decide what events you really want to compete in first.

Events

RoboOne

This is what started it all. Terukazu Nishimura started Robo-One in 2002. The name is a play on the kickboxing style K-1 (I guess R-1 was a little too oblique). In the beginning, the robots were prone to falling over and very shaky (it seemed like every 'bot had Parkinson's disease). Nowadays, the robots can do cartwheels, toss balls and books around a table, and are efficient enough to last for almost an hour before the batteries need to be replaced.

RoboOne events have evolved quite a bit since they began. In the beginning, there was just wrestling. This is still the mainstay of RoboOne. It's certainly incredibly fun. If you like combat robots, RoboOne takes the wheels off and makes the whole sport even more enjoyable. The basic concept is very much like boxing — a three-minute match, trying to knock the other guy down for 10 seconds.

The other major event in RoboOne is demonstration. This is the ballet of robotics. You program your android to make the best moves possible. I've seen RoboOne's spin on their heads like break-dancers, do cartwheels, complex dance routines — you name it. And that's the goal of this event — you get to write the rules. You can make your robot do whatever tricks you want. Just make sure that your moves are better than everyone else's. This event is really the premier showcase event at ROBOGames. If you want to show off, this is the best place to do it.

Other RoboOne events include the toss (throwing a ball at a target and seeing how close you can get to the center), the eagle — which is a James Bond style obstacle course, and the stairs, which is the third most popular event after wrestling and demonstration. All you have to do is climb up and down six stairs.

HuroSot

HuroSot stands for HUmanoid RObot SOccer Tournament, which is a division of FIRA — the Federation of International Robot-soccer Association (a play of FIFA.) Of the three android events, HuroSot is the only fully autonomous event, and certainly the most difficult. There are four sub events within HuroSot: the robot dash, in which the bots must run forward about three feet, stop, and run backwards to the starting line; the obstacle run, where robots have to run around a small maze-like course; the penalty kick, which

> “Well camper, if it’s an android you want, get off your duff and build one! Or at least buy one and get modding.”

Photo 1

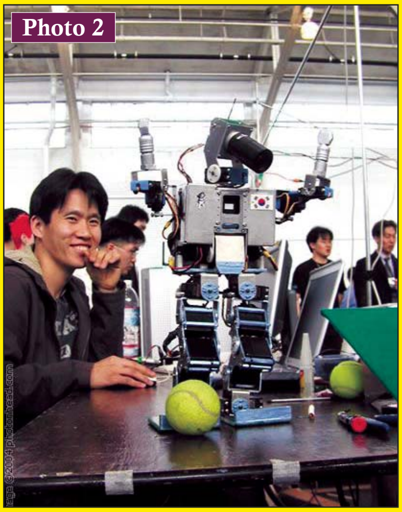


Photo 2

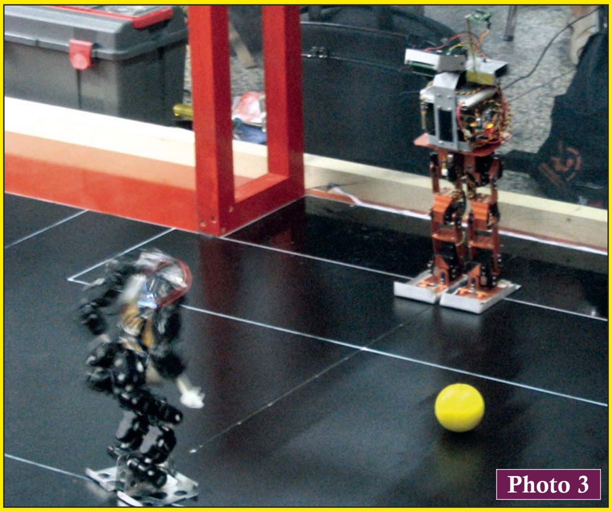


Photo 3

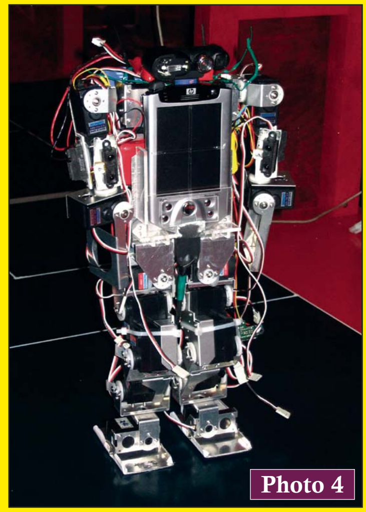


Photo 4

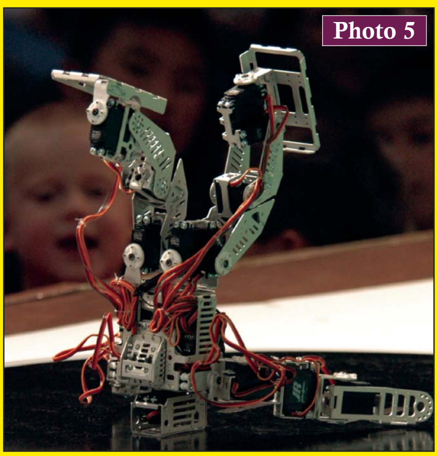


Photo 5

Photo 6

Photo 7

PHOTO 1. GOOOOOOOOOOOOOOOOOOOAAAAAAL!

PHOTO 2. Building a working android is quite possibly the proudest thing you can do!

PHOTO 3. A HuroSot free kick match. Look, the goalie has a real tough job.

PHOTO 4. A little tip: PDAs make for excellent brains for your android.

PHOTO 5. I can’t stand on my head, how does the Pirkus do it?

PHOTO 6. The android soccer match is way better than Nintendo or X-Box.

PHOTO 7. This little guy is controlled with a cell phone! The things they come up with these days ...

is one-on-one robot soccer (you must play both goalie and kicker); and the lift and carry which tests how much weight your robot can hold without falling over.

Android Soccer

Android soccer was invented for those control freaks (such as myself), who don't want to wait for the robots to perform autonomously. You want the robot to be remote controlled, and do as it's told, dammit! Just like real soccer, there are high points and low points. Having four or five robots surround the goal and try to make a play is incredibly exciting and tense — the crowd really gets charged up! And just like real soccer, more often than not, the goalie makes the save or the kicker misses the net, and no one scores. But when someone does score, the crowd goes wild.

It is, of course, possible to compete in all three competitions. No one has ever done it, but you could certainly be the first!

Once you know which events you'll compete in, it's time to decide what robot to use. There are excellent robots available on the market. The RoboNova, Pirkus, Plen, KHR-1, KHR-2, HRP-2m, Manoi, and others can all be purchased on-line. Some come assembled, some are kits, some are as cheap as $850. All of these are competitive out of the box.

Which isn't to say that they can't be made significantly more competitive by modding them. Matt Bauer, Tony Ohm, Dan Albert, and I all significantly modified our RoboNovas before last year's event. Matt added gripper hands, a camera, swiveling hips and more batteries in the feet (which also lowered the bot's center of gravity and improved its walking ability). Tony had the biggest changes, adding eight servos total, to his hips, thighs, and wrists. Dan and I both converted ours from infrared (which is really ineffective for most robots) to Zigbee wireless for communications and used Sony Playstation controllers for control. This didn't make the robots any stronger or more articulate, but we did greatly improve the ability to communicate with the robots — and if you're robot isn't getting your commands, it doesn't matter how powerful it is.

The other option is, of course, to build your own android from scratch. If you want to go this route — good for you! This is the best way to learn, and you'll certainly be cooler than all the people who bought kits. Before you start building your robot, here are some tips on building successful androids:

• Focus on perfecting the robot's walking ability. Your robot should be able to walk four feet or 10 steps without falling down. Nothing else matters if you can't do this.

• The more you can spend on servos, the better. The $10 HS-300s won't work. They'll strip and you'll have to throw them out. Get the highest torque servos you can possibly afford for the legs, and the second best for the arms. The newer digital servos can give you as much as 333 ounces of torque per square inch at six volts (but the 125 oz/in digital servos will work). Saving money on cheap servos will end up costing you more money when all the servos die and you have to throw them out and buy new ones.

• Use aluminum for the frame, unless you can afford titanium and know how to bend it. Steel is too heavy, and almost any plastic (include polycarbonate) isn't strong enough to withstand the forces on it.

• Make the foot as long and wide as the rules will allow. Generally, that means the foot length is 60% of the leg length or 30% of the body length. It's certainly possible to make it smaller (including eliminating the foot entirely and balancing on a single point), but it's generally easiest to have a big foot.

• Once you've perfected your robot's ability to walk and balance without falling down, work on increasing the speed. If you can move even a little faster than the other robots, you're at a huge advantage. This is immediately negated the second you fall down.

ANDROID EVENTS RULES SUMMARY

HuroSot

• Robot must be fully autonomous.

• Robots are grouped into three sizes: small (up to 50 cm/19-3/4" tall with a 14 cm/5-1/2" foot); medium (80 cm/31-1/2" tall, with a 20 cm/7-3/4" foot); and large (150 cm/59" x 35 cm/13-3/4").

• Robots may have sensors, but all sensing must be human equivalent (for example, vision is okay, but sonar is not.).

• Humans may not touch the robots during play.

Android Soccer

• Robots are R/C. You can use 75 MHz, WiFi, IR, or Bluetooth. You can use any kind of controller (Playstation, PC, joystick, etc.).

• Robot maximum height is 37 cm/15".

• 3-on-3 competition — You get a total of three robots to play. You can, in theory, have one person controlling all three, but practically, it's easier to have one human per robot.

• Robots must follow human soccer rules — no hitting, and certainly no flopping.

RoboOne

• Robots can be autonomous or R/C. Like soccer, you can use almost any freq to control.

• Robot maximum height is 37 cm/15".

• Robot's feet length can be no greater than 60% of leg height, and foot width can be no more than 40% of leg height.

• Wrestling is won by one robot knocking the other off its feet for 10 seconds. If your robot falls down by itself, it is not considered knocked out.

The above are rule summaries. Complete rules for all events are at **http://robolympics.net/events** — you should check each rule set for exact details.

Photo 8

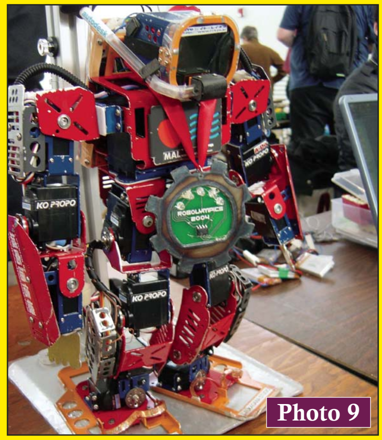


Photo 9

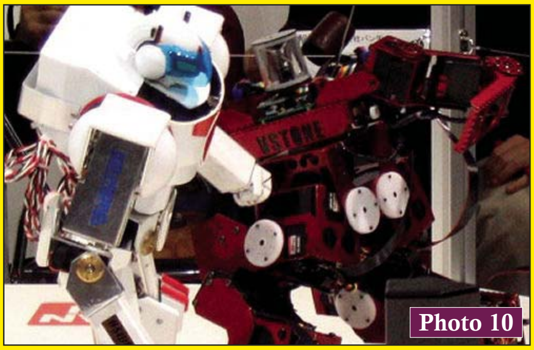


Photo 10

Photo 11

PHOTO 8. Some HuroSot builders and their androids.

PHOTO 9. Winning a medal at ROBOGames is the ultimate glory.

PHOTO 10. Modifying a RoboNova makes for an excellent fighter (note the extended legs, hips, and arms).

PHOTO 11. Italy better watch out.

- Get good gyros or accelerometers, and make your robot able to constantly maintain its balance (this is called proprioception or kinesthesia). Many androids don't have a sense of "up" or "falling" and will often "walk" while laying flat on their backs (thus, going nowhere). Give your robot a cochlea!

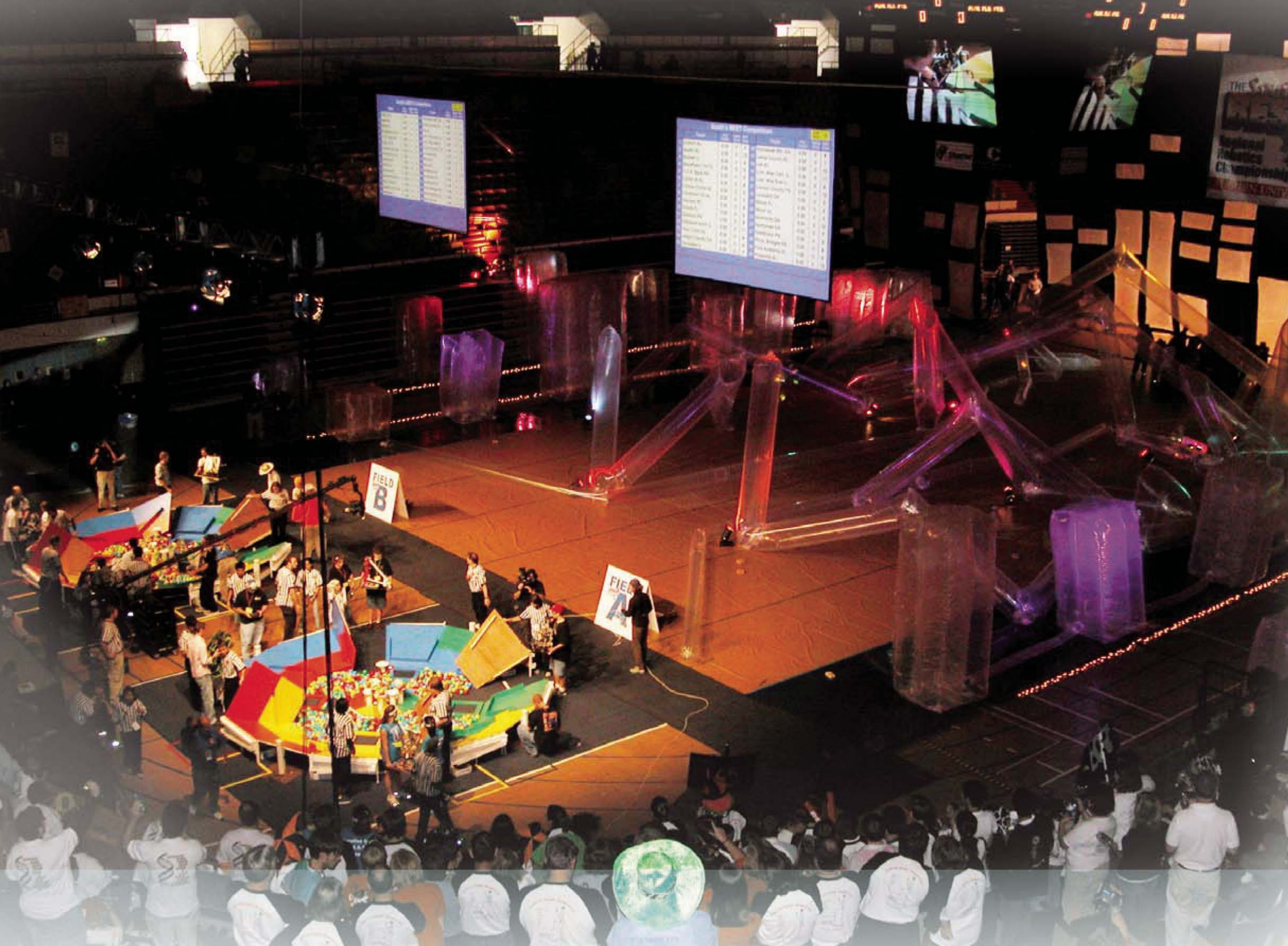
- Be able to self-right. Make your robot self-aware so that it can stand up again immediately when it does fall down.

- Use an electronic compass in-line with your walking program to keep a constant bearing so you're not drifting off course.

- If you buy a robot platform (e.g., a RoboNova), all of the above advice still applies.

So how do you proceed? Well, first figure out what both your time and money budgets are. If you're an experienced robot builder, you can probably go ahead and build one from scratch. If you haven't built many robots, or you don't have a lot of time, you should start with a kit and modify it. Again, modifying a kit isn't required, but it will make your robot much more competitive.

Androids are some of the most challenging and rewarding robotics projects out there. Going to a robot competition not only lets you meet other robot builders, but it will also force you to improve your android well beyond what you'd do if you were just working against yourself. If you want to see robotics grow to its full potential, there's nothing like an android to push you beyond your limits. **SV**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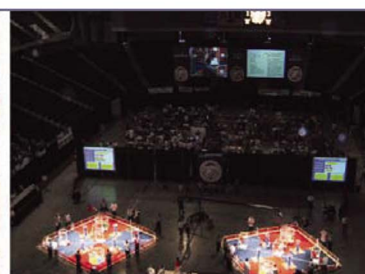


EVENTS CALENDAR

Send updates, new listings, corrections, complaints, and suggestions to:
steve@ncc.com or FAX **972-404-0269**

Only 10 more robot competitions on the calendar for 2006! They're spread out all over the world, so you shouldn't have any trouble finding one nearby to attend. November and December bring events in Alabama, Hawaii, Nevada, Pennsylvania, and Texas, as well as in Austria, Canada, Japan, and Spain.

Of particular interest in November is the All Japan MicroMouse Contest. If you have a chance to catch this one, you'll be amazed at these speedy little maze-solving robots.

Know of any robot competitions I've missed? Is your local school or robot group planning a contest? Send an email to steve@ncc.com and tell me about it. Be sure to include the date and location of your contest. If you have a website with contest info, send along the URL as well, so we can tell everyone else about it

For last-minute updates and changes, you can always find the most recent version of the Robot Competition FAQ at Robots.net: **http://robots.net/rcfaq.html**

— R. Steven Rainwater

November

12 **AESS National Robotics Contest**
Barcelona, Spain
Sumo, mini sumo, and other events for autonomous mobile robots.
http://aess.upc.es/cosursrobot

18 **DPRG RoboRama**
The Science Place, Dallas, TX
Events include Quick-Trip, line-following, wall-following, T-Time, and Can-Can.
www.dprg.org/competitions

18-19 **Eastern Canadian Robot Games**
Ontario Science Centre, Ontario, Canada
Multiple events including fire-fighting robots, sumo, BEAM photovore, BEAM solaroller, a walker triathalon, and art robots.
www.robotgames.ca

24-25 **Hawaii Underwater Robot Challenge**
Seafloor Mapping Lab, University of Hawaii, Manoa, HI
ROVs built by university and high-school students compete in this event, which is part of the MATE (Marine Advanced Technology Education) series of contests.
www.mpcfaculty.net/jill_zande/HURC_contest.htm

24-26 **All Japan MicroMouse Contest**
Nagai City, Yamagata, Japan
Includes Micromouse, Micromouse Expert level, and Micro Clipper events.
www.robomedia.org/directory/jp/game/mm_japan.html

December

1-2 **Texas BEST Competition**
Moody Coliseum, SMU, Dallas, TX
In the Texas BEST Competition, students and corporate sponsors build robots from standardized kits and compete in a challenge that is different each year.
www.texasbest.org

Robotics Showcase

Tune in each month for a heads-up on where to get all of your "robotics resources" for the best prices!

BY GORDON MCCOMB

Finding and Entering Robot Competitions

You may remember the combat robot craze a few years ago. At one time, there were three TV programs broadcasting the mayhem from battles around the world. Combat competition was one of the fastest robotics genres, and looked unstoppable. But if you go by the TV shows alone — none of which are still on the air except in reruns — you might think this whole notion of battling bots has gone the way of the Pet Rock. To the casual observer, robot competitions have all but ended.

That, of course, is far from the truth. Television has a way of altering our perception of reality. Though the fad of the televised robot war-style battles has come and gone, competitions are alive and well, from the lowly line-follower to the smash 'em, crush 'em fights of remotely-controlled stainless steel 'bots. Just because it's not on TV doesn't mean it's disappeared!

Examples of Robotics Competitions

Before looking at some of the more popular robot competitions (or challenges, as they are often referred to when in an academic setting), let's explore a few reasons why you'd want to bother in the first place. Basically, it all comes down to applying robotics technology and programming to achieve a stated goal, while at the same time having a little bit of fun. Building a robot tends to be an open-ended effort, and pitting the current version of your robot against someone else's can help you improve your design, skill, and knowledge.

Most non-builders associate combat fights as robotic competition but, in fact, there are far more non-destructive programs out there. Some — like the Trinity Firefighting contest held each year in the spring in Hartford, CT — are world famous. But most are ad hoc games set up by local robotics user groups. The competitions/challenges are varied, and often reflect the personalities and skill levels of the group members. The Dallas Personal Robotics Group, which meets weekly in Dallas, TX, is one of the more active groups that regularly holds competitions. A rundown of their events are good examples of what you might find elsewhere:

• *Mini Sumo*. Robots that fit a certain weight and size standard (must fit in a 100 mm square) face off in a miniature circular sumo arena. The idea is simple: Your robot must push the other robot out of the arena. Sounds simple enough maybe, but this isn't a remote controlled event like most robot combat. Your bot must identify the opponent, work to push the opponent off the area, while at the same time know not to cross outside the boundaries, or else it will be disqualified.

• *Quick Trip*. A variation of the path navigation problem, where a robot must travel within a preset area. The path is a simplified straight line back and forth, but don't be so quick to think this is easy. If the robot veers off course, or confuses the relay lines, it's disqualified. A variation on the theme popular with the group is T-Time, which has a more complicated path to follow.

• *Line-Following*. One of the easier challenges in its simple forms, line-following demonstrates the ability of a robot to identify a contrasting line on the floor, and trace it from start to end. Generally, the robot that can complete the course in the fastest time possible, without losing the line completely, wins. This is a great competition for any group because the complexity of the test area can be changed to enhance the challenge for more experienced builders. Some groups have pre-marked tiles they lay down on the ground, so that the course changes each time.

• *Wall-Following*. Another navigation competition, using sensors of some kind to detect walls. The goal is to get the robot to travel from point A to point B by using the physical wall of a room.

• *Can Retrieval*. The robot must locate and retrieve one or more empty 12-ounce beverage cans.

Additional competitions that are fairly common include mazes, where a robot must successfully solve a maze; ball collecting, wherein the robot finds a pool, tennis, or ping pong ball and brings it back; and soccer, where a fully autonomous robot plays traditional soccer (football for outside the US). Some of competitions are group

sports, where a team of robots compete against another team.

Finding a Competition

As already noted, most robotics competitions are sponsored by local user groups. There are other choices if you're a student in school. A nationwide (and international) event called FIRST (For Inspiration and Recognition of Science and Technoogy), brings school groups together to compete in general robotics and LEGO-based challenges. Many colleges and universities that offer a robotics or mechanical engineering program support their own competitions, and sometimes work with sister schools to put on major events. You'll want to talk with your faculty advisor to determine if your school offers a formal robotics competition program. If they don't, consider helping them start one.

In many urban areas of the country, you can find at least one robotics user group, and these groups are the natural springboards for competitions. Many group meetings are held in business parks, school auditoriums, or someone's home. Monthly meetings are the most common, and they tend to be informal, with show-and-tell and member presentations, along with occasional announced competitions.

Once you've found a group, you can determine which competitions they regularly support. If one interests you, be sure to get a list of the competition rules, so that if you enter your 'bot, it won't be immediately disqualified if it weighs too much, is too large, or has some other feature that isn't allowed. Talk with other members about the competition, and ask for pointers and feedback. Though it is a competition, most user group members are there to share ideas, and are more than willing to help out a potential winner in the next challenge. Only the most hardcore of competitors keep the secrets to themselves, and you can usually identify those fairly quickly. Let them have their fun while you have yours.

If there's no user group near you, consider starting it yourself. All it takes is a desire and at least one other member. Meetings can be held wherever it is convenient. At my local user group in San Diego, CA, we've sometimes met at a nearby electronics store when our regular meeting place has been unavailable. Once the group is formed, you can create competitions, and invite other members to participate.

Sources

Here is a list of many national and international competitions, including those that are only open to full-time students. I've also thrown in a number of local user groups. Web pages or message boards for the local groups are provided, along with their general location. Do note that user group home pages can change fairly frequently, especially if the group doesn't have its own unique domain name. If a group's page is no longer available, you may still be able to find it using a Google search.

Art & Robotics Group (ARG)
www.interaccess.org/arg
Canada, Ontario, Toronto
User group, discussion board, and latest news on the artistic side of robotics.

Atlanta Hobby Robot Club
www.botlanta.org
Georgia, Atlanta

Battlebots
www.battlebots.com
Just to show combat robotics is not dead!

Botball
www.botball.org
Regional competitions, which also include a workshop and construction seminars. The specific challenges vary each season.

Carnegie Mellon Robotics Club
www.roboticsclub.org
Carnegie Mellon University

Central Illinois Robotics Club
circ.mtco.com
Illinois, Peoria
Says the site: "The Central Illinois Robotics Club was founded ... in an effort to promote, educate, explore, and compete in the field of hobby robotics. The club is located in the greater Peoria area and meets monthly."

Chicago Area Robotics Group
www.chibots.org
Illinois, Chicago
Very active slate of competitions.

Connecticut Robotics Society
www.ctrobots.org
Connecticut, Hartford
As per the website: "We are a unique group of friends, experimenters, and mad scientists who meet monthly in Hartford, Connecticut ... Our interests are in electronics, mechanics, fun, and the sciences involved in automation and homebuilt robots."

DARPA Grand Challenge
www.darpa.mil/grandchallenge
Major US-sponsored competition that involves a serious quest to demonstrate a fully autonomous outdoor vehicle that can travel hundreds of miles.

Dallas Personal Robotics Group (DPRG)
www.dprg.org
Texas, Dallas
Projects, tutorials, articles. The DPRG also sponsors the well-received RoboRama competitions. Events include line-following, sumo, firefighting, and others. See **www.dprg.org/dprg_contests.html**.

Denver Area Robotics Club
www.ranchbots.com
Colorado, Denver

HomeBrew Robotics Club
www.hbrobotics.org
California, San Jose

KISS Institute for Practical Robotics (KIPR)
www.kipr.org
In the words of the website: "KISS Institute for Practical Robotics (KIPR) is a private non-profit, community-based organization that works with all ages to provide improved learning and skills development through the application

of technology, particularly robotics. We do this primarily by providing supplementary, extra-curricular, and professional development classes and activities. KISS Institute's activities began in 1993." KIPR also sponsors the annual Bot Ball tournament for middle and high school students.

Nashua Robot Club
nashuarobotbuilders.org
New Hampshire, Nashua

Phoenix Area Robot Experimenters
www.parex.org
Arizona, Phoenix

Portland Area Robotics Society
www.portlandrobotics.org
Oregon, Portland

From the site: "The Portland Area Robotics Society is a club formed to help those interested in learning about and building robots. The club involves professionals, amateurs, students, college professors, engineers, artists, hobbyists, and tinkerers. PARTS will help explore all aspects of robotics for its members, and work toward expanding communication between robot enthusiasts. PARTS members share ideas, experience, and enthusiasm for building robots."

Robocup
www.robocup.org

Robotics soccer. So far, there are no Beckhams in the robotics field, but they're getting close!

Robot Competititon FAQ
robots.net/rcfaq.html

Useful generic information on all types of robot competitions.

RobotBuilders.Net
www.robotbuilders.net

Umbrella website for various specialty Internet-based robot building clubs. Some competition events are supported.

- B-9 Club
- Robot Club
- R2-D2 Builder's Club
- The Drone Room (Silent Running)

Robot Competition Wiki
en.wikipedia.org/wiki/Robot_competition

General page on various robotic competitions. Regularly updated.

Robotics Society of Southern California
www.rssc.org
California, Fullerton

San Diego Robotics Society
www.sdrobotics.org
California, San Diego

San Francisco Robotics Society of America
www.robots.org
California, San Francisco

The San Francisco Robotics Society of America also sponsors the annual Robot Sumo conference.

Seattle Robotics Society
www.seattlerobotics.org
Washington, Seattle

SRS has a major presence on the Internet, and publishes the Encoder, an online technical journal on amateur robot building.

Southern Oregon Robotics Club
www.sobotics.org
Southern Oregon

Sponsors RoboMaxx and other competition events.

The Robot Group
www.robotgroup.org
Texas, Austin

From the website: "The Robot Group was founded in the spring of 1989 by a small group of Austin, TX artists and engineers who shared a common vision: utilizing technology to provide and explore new mediums for art. Through the synergy of fusing art and technology, The Robot Group has stimulated the public into a playful interest in high technology, and art now has new vehicles for effecting culture."

The Robotics Club of Yahoo (TRCY)
groups.yahoo.com/group/theroboticsclub

Major Internet-based group of robotics enthusiasts. Visit to get ideas about competitions, and to help find local groups.

Titan Robotics Club
www.titanrobotics.net

International School Robotics Club. This is for high-schoolers and middle-schoolers who are interested in robotics.

Triangle Amateur Robotics
triangleamateurrobotics.org
North Carolina, Raleigh

Trinity Firefighting Content
www.trincoll.edu/events/robot

The Trinity Firefighting Contest is an annual national event that tests the skill of robots to locate and put out the fire of a small candle in a model of a building.

Twin Cities Robotics Group
www.tcrobots.org
Minnesota, St. Paul

Twin Citites Robotics Group is self-described as "a loose affiliation of people interested in robots, located in the Twin Cities metro area." The site hosts a number of useful resource pages, includes articles (identified by skill level), useful links, and colorful photos of the monthly meeting showing people and robots in action.

Union College Robotics Club
www.vu.union.edu/~robot
New York, Schenectady

US FIRST
www.usfirst.org

Parent site to FIRST, "For Inspiration and Recognition of Science and Technology." Supports numerous competitions and challenges across the country. FIRST and FIRST LEGO Leagues are both international events (**www.firstlegoleague.org**).

Vancouver Island Robotics
www.vancouverislandrobotics.org
Canada, Vancouver Island

Vancouver Island Robotics sponsors workshops and day camps. **SV**

ROBO-LINKS

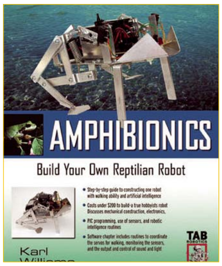
For the finest in robots, parts, and services, go to www.servomagazine.com and click on Robo-Links to hotlink to these great companies.

Mind Candy For Today's Roboticist

The *SERVO* Store

Amphibionics

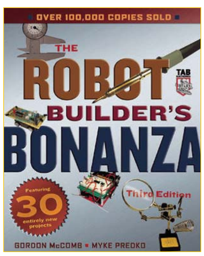
by Karl Williams



This work provides the hobbyist with detailed mechanical, electronic, and PIC microcontroller knowledge needed to build and program a snake, frog, turtle, and alligator robots. It focuses on the construction of each robot in detail, and then explores the world of slithering, jumping, swimming, and walking robots, and the artificial intelligence needed to make these movements happen with these platforms. Packed with insight and a wealth of informative illustrations. **$19.95**

Robot Builder's Bonanza Third Edition

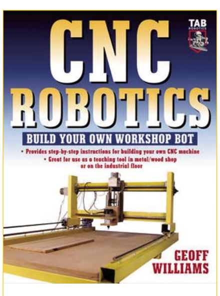
by Gordon McComb / Myke Predko



Everybody's favorite amateur robotics book is bolder and better than ever — and now features the field's "grand master" Myke Predko as the new author! Author duo McComb and Predko bring their expertise to this fully-illustrated robotics "bible" to enhance the already incomparable content on how to build — and have a universe of fun — with robots. Projects vary in complexity so everyone from novices to advanced hobbyists will find something of interest. Among the many new editions, this book features 30 completely new projects! **$27.95**

CNC Robotics

by Geoff Williams



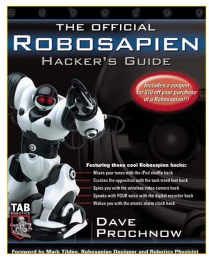
CNC Robotics gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80 percent of the price of an off-the-shelf bot — and that can be customized to suit your purposes exactly, because you designed it. Written by an accomplished workshop bot designer/builder, this book gives you all the information you'll need on CNC robotics! **$34.95**

SERVO CD-Rom

Are you ready for some good news? Along with the first 14 issues of *SERVO Magazine*, all issues from the 2005 calendar year are now available, as well. These CDs include all of Volume 1, issues 11-12, Volume 2, issues 1-12, and Volume 3, issues 1-12, for a total of 26 issues all together. These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **$24.95 – Buy 2 or more at $19.95 each!**

The Official Robosapien Hacker's Guide

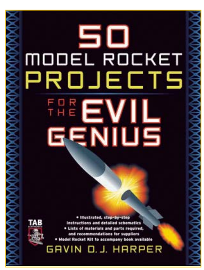
by Dave Prochnow



The Robosapien robot was one of the most popular hobbyist gifts of the 2004 holiday season, selling approximately 1.5 million units at major retail outlets. The brief manual accompanying the robot covered only basic movements and maneuvers — the robot's real power and potential remain undiscovered by most owners — until now! This timely book covers all the possible design additions, programming possibilities, and "hacks" not found anyplace else. **$24.95**

50 Model Rocket Projects for the Evil Genius

by Gavin D. J. Harper



Yes, as a matter of fact, it IS rocket science! And because this book is written for the popular Evil Genius format, it means you can learn about this fascinating and growing hobby while having run creating 50 great projects. You will find a detailed list of materials, sources for parts, schematics, and lots of clear, well-illustrated instructions. **$24.95**

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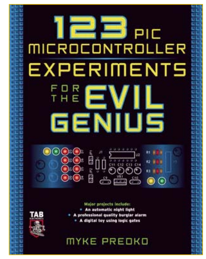
123 PIC Microcontroller Experiments for the Evil Genius

by Myke Predko



Microchip continually updates its product line with more capable and lower cost products. They also provide excellent development tools. Few books take advantage of all the work done by Microchip. *123 PIC Microcontroller Experiments for the Evil Genius* uses the best parts, and does not become dependent on one tool type or version, to accommodate the widest audience possible. Building on the success of *123 Robotics Experiments for the Evil Genius*, as well as the unbelievable sales history of *Programming and Customizing the PIC Microcontroller*, this book will combine the format of the evil genius title with the following of the microcontroller audience for a sure-fire hit. **$24.95**

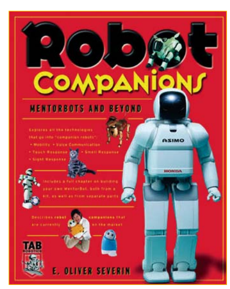
PIC Basic Projects

by Dogan Ibrahim

Covering the PIC BASIC and PIC BASIC PRO compilers, *PIC Basic Projects* provides an easy-to-use toolkit for developing applications with PIC BASIC. Numerous simple projects give clear and concrete examples of how PIC BASIC can be used to develop electronics applications, while larger and more advanced projects describe program operation in detail and give useful insights into developing more involved microcontroller applications. **$29.95**

Robot Companions

by E. Oliver Severin



Inside *Robot Companions*, you'll find all the details, plans, and information you need to make a robot partner part of your daily life, at a price you can afford. Author E. Oliver Severin, originator of some of the technologies that make robots friendly, useful, and educational, shows you how to find or build your own robot helpmate — either from commercial kits or an assembly of separate, off-the-shelf parts. **$24.95**

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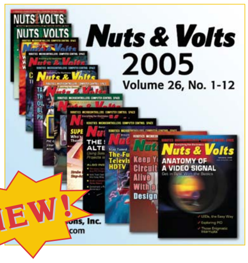
Mind Candy For Today's Roboticist

Nuts & Volts CD-Rom

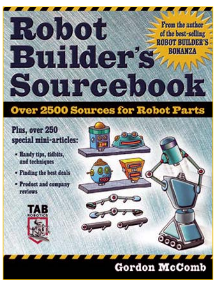


NEW!

Here's some good news for *Nuts & Volts* readers! Along with all 12 issues of *Nuts & Volts* from the 2004 calendar year, the 2005 issues are now available, as well. These CDs include all of Volumes 25 and 26, issues 1-12, for a total of 24 issues (12 on each CD). These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **$24.95 – Buy 2 or more at $19.95 each!**

Robot Builder's Sourcebook

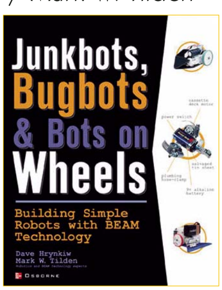
by Gordon McComb



Fascinated by the world of robotics, but don't know how to tap into the incredible amount of information available on the subject? Clueless as to locating specific information on robotics? Want the names, addresses, phone numbers, and websites of companies that can supply the exact part, plan, kit, building material, programming language, operating system, computer system, or publication you've been searching for? Turn to *Robot Builder's Sourcebook* — a unique clearinghouse of information for that will open 2,500+ new doors and spark almost as many new ideas. **$24.95**

JunkBots, Bugbots, and Bots on Wheels

by Dave Hrynkiw / Mark W. Tilden

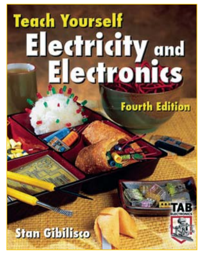


From the publishers of *BattleBots: The Official Guide* comes this do-it-yourself guide to BEAM (Biology, Electronics, Aesthetics, Mechanics) robots. They're cheap, simple, and can be built by beginners in just a few hours, with help from this expert guide complete with full-color photos. Get ready for some dumpster-diving! **$24.99**

Check out our online bookstore at www.servomagazine.com for a complete listing of all the books that are available.

Teach Yourself Electricity and Electronics — Fourth Edition

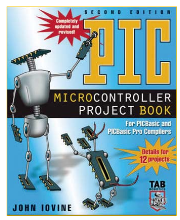
by Stan Gibilisco



Learn the hows and whys behind basic electricity, electronics, and communications without formal training. The best combination self-teaching guide, home reference, and classroom text on electricity and electronics has been updated to deliver the latest advances. Great for preparing for amateur and commercial licensing exams, this guide has been prized by thousands of students and professionals for its uniquely thorough coverage ranging from DC and AC concepts to semiconductors and integrated circuits. **$34.95**

PIC Microcontroller Project Book

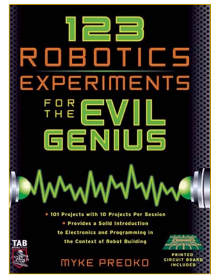
by John Iovine



The PIC microcontroller is enormously popular both in the US and abroad. The first edition of this book was a tremendous success because of that. However, in the four years that have passed since the book was first published, the electronics hobbyist market has become more sophisticated. Many users of the PIC are now comfortable shelling out the $250 for the price of the Professional version of the PIC Basic (the regular version sells for $100). This new edition is fully updated and revised to include detailed directions on using both versions of the microcontroller, with no-nonsense recommendations on which is better served in different situations. **$29.95**

123 Robotics Experiments for the Evil Genius

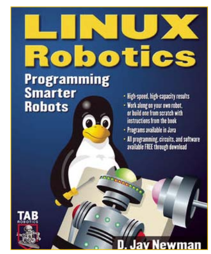
by Myke Predko



If you enjoy tinkering in your workshop and have a fascination for robotics, you'll have hours of fun working through the 123 experiments found in this innovative project book. More than just an enjoyable way to spend time, these exciting experiments also provide a solid grounding in robotics, electronics, and programming. Each experiment builds on the skills acquired in those before it so you develop a hands-on, nuts-and-bolts understanding of robotics — from the ground up. **$25.00**

Linux Robotics

by D. Jay Newman



If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need, plus complete training in doing original programming. **$34.95**

$20 each 15% off if you buy two or more.

From HomoSapien to RoboSapien

Before R2D2 there was R1D1

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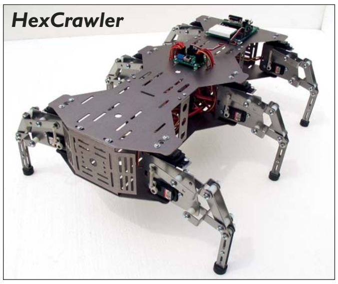
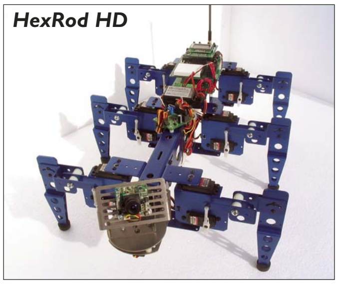
12 SERVO HEXAPOD KITS WITH TWO DOF LEGS

MANUFACTURER	Model	Length (in.)	Width (in.)	Height (in.)	Ground clearance (in.)	Weight w/o batteries & electronics (oz.)	Payload capacity (oz.)	Speed on horizontal ground	Body material	Leg material	Standard servos	Servo torque at 6V (oz.-in.)
Crustcrawler www.crustcrawler.com	HexCrawler	19.56	15.75	6	3.5	64	120	6 in/sec	5052 Aluminum	6062 Aluminum	HS-322HD	51
	HexRod HD	16	13	6.25	2.75	55.2	120	6 in/sec	5052 Aluminum	6062 Aluminum	HS-322HD	51
Joinmax www.mciirobot.com	Hexapod Monster	19.57	9.04	6.73	3.54	33.9	97.7	2 in/sec	ABS Plastic	ABS Plastic	JM-CB-1000	3.0Kgf.cm
Lynxmotion www.lynxmotion.com	EH2C-KT	13	16	5.5	3	48	32	12 in/sec	Lexan	Lexan/ Anodized Aluminum	HS-422	57
	Mini Hexapod Project	10.5	12.5	5	2.5	40	16	9 in/sec	Aluminum	Aluminum	HS-422	57
	AH2C-KT	13	13	7.5	5	52	32	7 in/sec	Aluminum	Aluminum	HS-422	57
	Walking Stick Project	20	15	7.5	5	50	40	8 in/sec	Aluminum	Aluminum	HS-475	76
Milford Instruments Ltd. www.milinst.com	Hextor P/N 5-780	18	13.5	9.5	3	56	53	6 in/sec	Expanded PVC	Expanded PVC	Supertec S03 – hips, Supertec S06 – knees	56 – hips, 111 – knees

HexCrawler



HexRod HD



Hexpod Monster

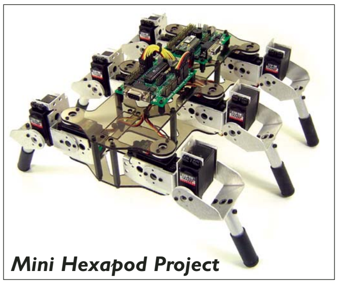
EH2C-KT

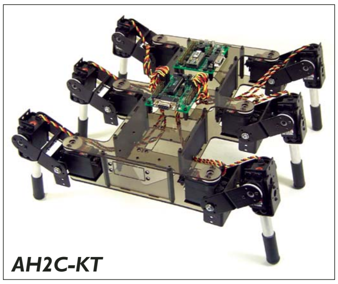
MATRIX

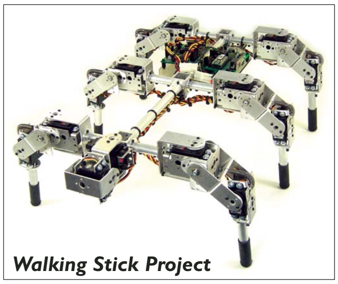
by Pete Miles

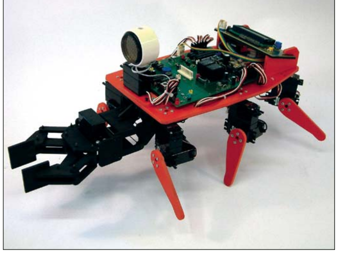
Upcoming topics include SBCs and H-bridges, sensors, kits, and actuators. If you're a manufacturer of one of these items, please send your product information to: **BrainMatrix@servomagazine.com** Disclaimer: Pete Miles and the publishers strive to present the most accurate data possible in this comparison chart. Neither is responsible for errors or omissions. In the spirit of this information reference, we encourage readers to check with manufacturers for the latest product specs and pricing before proceeding with a design. In addition, readers should not interpret the printing order as any form of preference; products may be listed randomly or alphabetically by either company or product name.

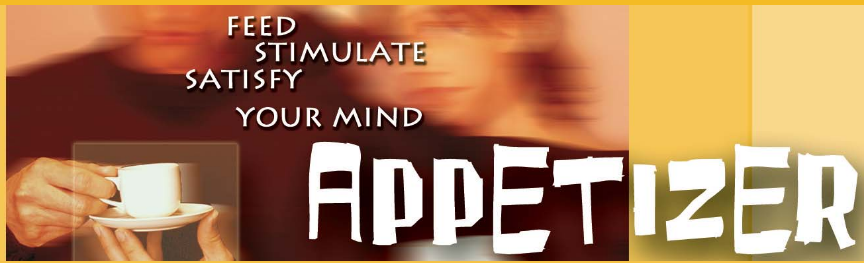
Servo speed at 6V sec/60 deg	Standard servo controller (included)	# of controllable servos	Standard microcontroller	Prototyping area for additional electronics (square in.)	Recommended battery type for servos	Recommended micro-controller for autonomous/remote control operation	Colors	List Price	Standard included electronics
0.15	Parallax Servo Controller	16	BS2 — Included	282	7.2V 3,000 mAh NiMH	Any	Graphite-Black	$695	Parallax USB Board of Education
0.15	Parallax Servo Controller	16	BS2	84	7.2V 3,000 mAh NiMH	Any	Blue-Black	$559	Parallax USB Board of Education, LCD App Mod.
0.18	JM-CB-1000	16	ATMEGA16L	20	1.5V AA (NiCd) Qty 5	PC Tether	Yellow-Grey	$390	Optional
0.16	SSC-32	32	Basic Atom 28	48	6.0V 1,600 mAh or 7.2 VDC 2,800 mAh NiMH	Atom 28	Black, White, Yellow, Tinted, or Clear Lexan	$470.70	Bot Board
0.16	SSC-32	32	Basic Atom 28	6	6.0V 1,600 mAh or 7.2 VDC 2,800 mAh NiMH	Atom 28	Black Anodized or Brushed Aluminum	$486.88	Bot Board
0.16	SSC-32	32	Basic Atom 28	48	6.0V 1,600 mAh or 7.2 VDC 2,800 mAh NiMH	Atom 28	Black Anodized or Brushed Aluminum	$597.13	Bot Board
0.18	SSC-32	32	Basic Atom 28	30	6.0V 1,600 mAh or 7.2 VDC 2,800 mAh NiMH	Atom 28	Black Anodized or Brushed Aluminum	$784.43	Bot Board
0.23 hips, 0.33 knees	Milford intelligent three-servo controllers, Qty 5	16	BS2sx	Expansion Port	7.2V 2,000 mAh NiCd	Any	Red-Black	£499.00	Walking co-processor, ultrasound scanning head, teaching LCD pendant, IR remote control, touch sensors


Mini Hexapod Project


AH2C-KT


Walking Stick Project

Hextor P/N 5-780




Why It's Great to be the BEST

by Dr. George Blanks, with Steve Marum and Ted Mahler

For six years now, I have volunteered my time with a non-profit robotics competition based in Dallas, TX called BEST Robotics, Inc. It's an all-volunteer group of hundreds of folks at 31 competition sites ("hubs") in 14 states ... and growing. This fall, around 675 schools — over 11,000 students — will participate in the six-week-long competition, which is underway.

I thought the "BEST" way to present what this competition is all about was to submit a welcome letter that appears in the front of our annual report, which can be downloaded at **www.bestinc.org** ...

Why Do We Do Our BEST?

Why do we do this? Why do teachers, mentors, and hundreds of BEST volunteers devote countless hours of their personal time to this program? What is it about BEST that is worth the effort?

One answer can be seen in a small piece of the event that often goes unnoticed. In this tiny slice of time, a student's actions become a microcosm of the entire reason for BEST. It happens only in the frantic few minutes before a round of competition starts. Those final few seconds when all eyes are on them, the crowd noise is deafening, and the time pressure is mounting. It happens when that student makes the sudden realization that their robot is not working.

What happens then reflects everything that student has learned in BEST. In that pressure cooker environment, young students walk through a cognitive detective process worthy of any NASA mission controller. Without their adult mentors to help, under time pressure and under emotional strain, they encounter a remarkable 60-second life lesson.

Most push through. They do it because in the proceeding six weeks of design, test, and redesign, they have learned a skill. They have learned how to break the problem barrier.

Steve Marum and Ted Mahler — Co-founders of BEST Robotics, Inc.

Breaking the problem barrier is the realization that a problem is not an endpoint, but only an answer not yet found. Being able to break the problem barrier divides students who can from those who can't. Each year, BEST helps students push through that barrier.

Life is a set of problems. A broken water heater, a flat tire, a tax form to fill out, a jammed manipulator arm on a robot driving on the surface of Mars, two nations on the brink of war — they are all problems. Once the problem barrier is broken, problems are replaced with process.

BEST changes mindsets. BEST places students in a situation that conditions their mind. It is a situation that flows from concept, to physical structure, and finally to operational use. Using robot design and competition, BEST presents an opportunity for students to break the problem barrier.

BEST appears first as an almost insurmountable problem and ends with the accomplishment of a solution; in the middle, a process. That process is the key. Somewhere in that process the problem barrier is broken and, in these young minds, the perception of a problem is changed.

Our country, our world, needs these changed young minds. Young minds that understand problems are not endpoints, but undiscovered answers waiting for the correct process. That's why we do this. That's why we continue to do our BEST. SV

BEST™
Robotics Inc.
Boosting Engineering, Science & Technology™

Then and NOW

ROBOT VACUUM CLEANERS AND LAWN MOWERS

by Tom Carroll

It's Saturday morning and you've slept in. The bed is soft and cozy when you are awakened to the whir of a motor off in the distance. You look at your alarm clock and see the blue "8:00" shining back at you. Oh, yeah, it's time for my robot vacuum cleaner to begin its daily ritual. Then, suddenly, you hear a louder whirring noise outside your window as your robot lawn mower begins it weekly chore. "Dang," you mutter to yourself, "I've got to re-program those things to start later on Saturday; I need my sleep."

Ahh, the ubiquitous labor-saving tools of the modern age! These two appliances are the epitome of a robot experimenter's goal. Every homeowner would like a lawnmower that can decide when the grass needs to be mowed, have it exit from its storage area, and mow the lawn completely without a person's involvement. It must safely perform this task effectively in the midst of people, obstacles, children's toys, and pets. Today's homemaker wants the same thing in a vacuum cleaner for carpets and floors, but operating within the ever-changing environment of a home. Tall orders? Possibly — several decades ago.

Robot Vacuum Cleaners Design Dilemma

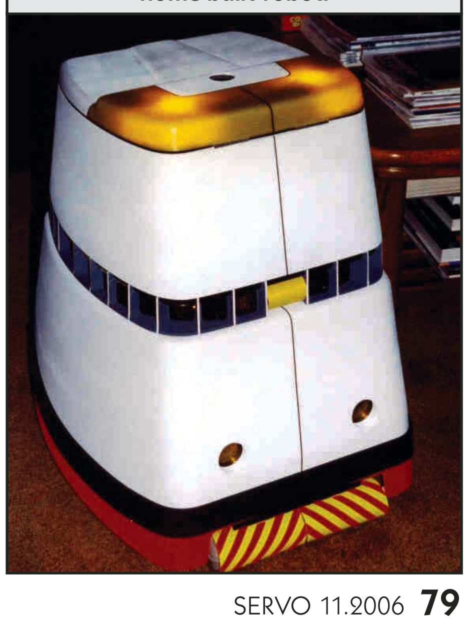
The first experimenter-built robot vacuum cleaners that I remember all used a "Dust Buster" type of battery-operated, hand-held vacuum cleaner mounted to a mobile robot base. These early machines were more of an experiment in functionality than actual usefulness. It did not take experimenters long to discover that a vacuum cleaner's cleaning power was not just a result of the vacuum level attained in "inches of water," but also the volume of air moved in cubic feet per minute at that lowered pressure. We've all seen the TV ad where the hand-held vacuum cleaner is attached to a large funnel and the spokesperson sucks a bowling ball onto the funnel and lifts it up. This in no way demonstrates the cleaning ability of a vacuum cleaner as we could easily do the same thing sucking with our mouth. If the funnel had an effective area of only 20 square inches touching the 16-pound ball, less than one pound per square inch (or two inches of mercury) of vacuum (out of 14.7 PSI) suction with your mouth could allow you to lift the ball. Vacuum cleaner design is a bit more complex than just raw suction.

Figure 1 shows an early home-built robot vacuum cleaner that was a work of art, though a bit tall to clean under most furniture. Frank Jenkins of the Robotics Society of California demonstrated his home vac for our group 15 years ago. At 23 inches high and 44 pounds, HomeR was a bit larger than today's machines, but contained over 80 sensors. It used an Ampro 386SX board computer with four megabytes of memory. It also had a Black and Decker hand vacuum system built in for the sweeping function and could find its way back to a charging dock. This beautiful machine may not have been able to snake its way under a low coffee table, but it was one of the most stunningly-built robots that I had ever seen.

Today's robot vacuum cleaner designers have been "backed into a corner" of sorts as they soon realized that greater cleaning ability required a larger motor. A larger motor required a larger battery. Longer operating time also required a larger battery. A smaller, practical size was certainly more desirable for a typical homemaker. All of these requirements were hard to meet in a mobile robot. What was the designer to do?

The first step was to reduce the motor's power requirements, thus reducing the battery size and, therefore, the overall machine's size and

Figure 1. This is Frank Jenkins' home-built robot.



weight. Now, with less effective suction and "cleaning power," the designer was left with slowing the robot vacuum's speed down to have the nozzle over a given area for a longer period of time, or, devising an overall better nozzle arrangement augmented with rotating brushes or similar devices.

The designers of the best-selling robot vacuum cleaners actually took many more design aspects into consideration such as height above the carpet or floor, number and location of "nozzles;" shape of the air flow channels; shape, speed, and location of brushes; number of passes over an area, and many more aspects. Then comes the navigation and steering of the robot cleaner. Do you just allow the machine to bump into walls, reverse, and then go off in another direction like a sheep randomly eating grass in a meadow? Eventually, the machine finally covers the entire carpet in a given room — or does it?

Does it keep bumping into the same chair and table legs, only to miss many areas of the carpet? Does the designer need to add optical or ultrasonic sensors to allow the robot to travel parallel to a wall without touching it? Does one need to add a higher-level processor to bit-map a room? Do you need to add sensors to detect what parts of the carpet the machine has covered by detecting carpet fibers brushed in a specific direction? How does the robot regain its original path once it detects an obstacle and goes around it? Detecting a full dirt bin, orientation, low batteries, dangerous overhangs, and getting permanently stuck were other designer problem areas. Today's robot vacuum manufacturers have solved these and many other design issues.

The iRobot Roomba

There is no doubt to all of us that the iRobot Roomba is the run-away best selling "home robot" ever, with over two million sold and counting, after its September 2002 debut. Back then, everyone was talking about Dean Kamen's Segway Transporter, as this other small New England company quietly designed and produced what many say is the first truly useful consumer robot. This amazing product that people have called a 'low-flying flying saucer,' a "Frisbee on steroids,' and even a 'bathroom scale that walks' is in millions of homes around the world.

The overall design and basic shape and size were not iRobot's biggest hurdle; their problem was how to make the robot vacuum affordable to be able to be sold through major retail chains. There were already some capable — but very expensive — robot vacuum cleaners on the market. In the beginning, they decided that they needed a simple eight-bit processor and a small number of parts that could be easily machined or molded, much like toy manufacturers who create amazing devices for child-sized budgets. Uniquely enough, iRobot did have experience with toy manufacturing — their disastrous My Real Baby, a robot doll that failed miserably in the toy market.

Roomba Design Constraints

iRobot wanted the Roomba to be effective on both carpeted and hard floors. Designer Joe Jones wasn't after a 'cool' factor; he wanted as machine that would do a job well. Jones — the lead designer for the Roomba — designed it with an undercarriage containing the dirt collection pan and the revolving brushes that rise or lower according to the floor type. You may remember him as the co-author of the great book *Mobile Robots — Inspiration to Implementation*.

When Roomba encounters friction-causing surfaces such as carpet, the torque derived from the friction on the brushes causes the assembly to rise a bit, thus lessening the load torque. When the load lessens — such as on a hard floor — the brush assembly lowers. This seemingly complex action is created by a simple string and friction clutch arrangement to keep the cost down. A single motor is used for the brush assembly and the lifting/lowering system. Roomba utilizes a spinning side brush to push dirt from edges into the path of the main cleaning head (see Figures 2 and 3).

The next generation of Roombas uses the C programming language and is compiled with commercially available software. A 16-bit Freescale Semiconductor MC9S12 processor using only 2K bytes of RAM executes the algorithms. Several years ago, they came out with the Roomba Pro and Pro Elite. The Roomba Pro Elite model included a remote control that allowed users to navigate the robot vacuum around a room, set cleaning options, and turn the Pro Elite on or off with the touch of a button. The Roomba Pro Elite also featured a "MAX" cleaning mode for multi-room cleaning or high-traffic areas. The software featured one or two virtual walls and a "cliff-avoidance" detector that prevented the robot from falling down stairs. "These newer generations are able to determine how large the room is and plot the most effective cleaning tactic based on the room's layout," says Colin Angle, iRobot's CEO.

The current cheapest model — Roomba Red — costs $150, though I've seen it on closeout sales for less than $75. The Roomba Sage model has a longer-lasting battery that charges faster, for an additional $50. Roomba Discovery goes for $250, has auto

Figure 2. The inside of the Roomba.

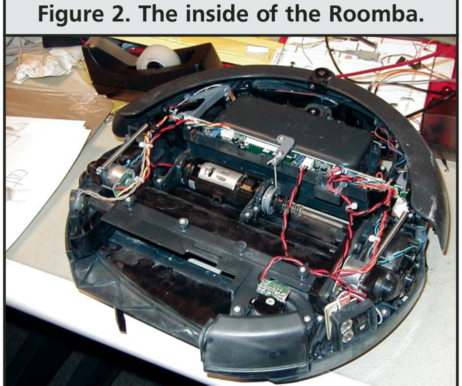
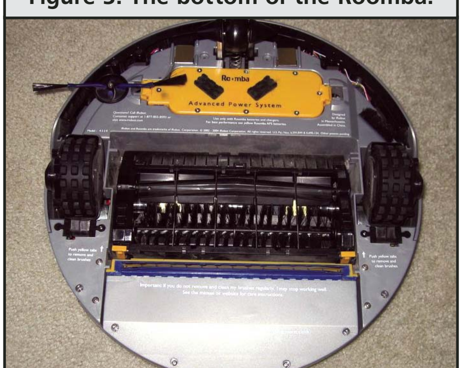


Figure 3. The bottom of the Roomba.



charging ability, and a larger trash bin, or, for $50 more, it can charge while hanging on the wall. Toss in an additional $30 ($330) for the Scheduler and you get the ultimate Roomba — one that you can schedule for the whole week's worth of cleaning.

Buyers must remember that the Roomba is not a deep-cleaning machine, just a daily 'touch up' device to keep your house presentable. You need to use a more powerful upright for deep cleaning and shag carpeting. Keep in mind also, that the Roomba is not pet-friendly. It won't attack your cat or dog, but it's a pretty sure thing that Fluffy will place it at the top of his enemy list.

The iRobot Scooba

iRobot's success with the Roomba made the step to the floor-scrubbing Scooba a natural direction to go. The Roomba did a good job of removing dust and dirt that was just lying on the surface of a hard floor, but most dirt adheres to floors and needs to be scrubbed off. This scrubbing action required a totally different type of cleaning system. As the company says: "Meet the Scooba Floor Washing Robot ... the world's first floor-washing robot for the home that preps, washes, scrubs, and dries your floor — all by itself.

Unlike mop and bucket methods that just spread dirty water around your floor, Scooba uses a fresh Clorox Scooba cleaning solution from start to finish. Figure 4 shows a diagram of how the solution is dispensed and sucked up after it's dirty. With the press of a button, the robot will leave your floors clean, dry, and ready to walk on. Scooba is simple to use, and safe on all sealed hardwood, tile, and linoleum flooring." What impressed me is the Scooba actually sucks up the dirty water from the first cycles and deposits it in another separate container that is emptied later. Figure 5 shows the interior of a Scooba.

Mowing the Lawn on Autopilot

The desire for a robotic lawnmower has been around about as long as the early vacuum cleaner ideas. Back in the mid '80s at a Robot Institute of America (RI/SME) conference, I took this photo of a robot lawnmower that was a bit more remote controlled than computer controlled (see Figure 6). Notice the toothed belt steering the four wheels to make it move in all directions like a crab, yet still be facing the same direction. It drew a substantial crowd of onlookers; pretty good from a bunch of industrial robot engineers.

Robot Lawn Mower Design Issues

Designers of robot mowers face some hurdles that aren't encountered by designers of robot vacuum cleaners. The number one issue is safety. Cutting grass is much more energy-intensive than sucking dirt off a carpet's surface, even with revolving brushes to assist in the task. Add to this many more square feet of grass in the typical yard than indoor carpeting and you have a need for a lot more energy on board a mower.

Build a machine with one to three spinning metal blades designed to cut things and you have a potential hazard to humans, animals, and property. Mowers have already been labeled hazardous machines by many government agencies and are required to have a "dead man's switch" that stops the blade (and engine) when the handle is released. This certainly does not stop the operator from running over a pile of small pebbles that can be slung in all directions. So, keeping in mind the "stupid factor," the manufacturers carefully evaluated the robot mower design process.

The RoboMower from Friendly Robotics

Lawn-tool company, Toro, markets a Robomower under the brand name iMow. Husqvarna — a division of a Swedish vacuum cleaner company, Electrolux — also sells a robotic lawn mower, the Auto Mower. But it is the Israeli company, Friendly Robotics, that leads the pack and has sold over 50,000 RoboMowers since 1998. Udi Peless and Shai Abramson — two Israelis with technical backgrounds — joined forces to produce the lawnmower back in 1995. Peless had already enjoyed quite a bit of success with a medical equipment start-up company and used his knowledge of navigation and control systems and Abramson's software background to start the company in a garage.

They were a bit overconfident in their ultimate success, but several million dollars and years later, they had a gasoline-powered "Lawn-Keeper" prototype in 1998. The first machine they had for sale used a 16-bit, 20 MHz Hitachi HS8 microcontroller to weigh inputs from various sensors and send controlling signals to the 150W drive wheel motors and a 750W cutter motor. They managed to sell 4,000 of these mowers by 2001. Later models changed the single cutter motor to three 150W motors, thus saving 300 watts. As any robot experimenter can

Figure 4. Scooba cleaning illustration.

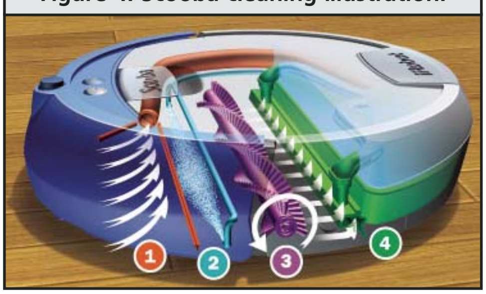


Figure 5. The inside of the Scooba.

Figure 6. An early robot lawnmower.

Figure 7. The RL1000 RoboMower and its dock.

Figure 8. Mower blades.

Figure 9. The RoboMower RL850.

attest to, it was the development of the software that offered them the greatest challenge, not the hardware.

Friendly Robotics credits the Roomba for boosting interest in its robotic lawn mowers. "Roomba has given us a lot of forward momentum," said Mike Dunigan, vice president of sales at Friendly Robotics, USA. He says that dogs, cats, and kids are safe around the Robomower. "Dogs bark at it about an hour before they finally give up on it," he said. "Cats hide." A slight pressure on any side of the Robomower will cause it to turn around, and the mower's blades shut off in less than a second if the machine is lifted off the ground.

The RL1000 RoboMower is the top-of-the-line and retails for about $1,800. It is designed to mow a lawn all by itself (Figure 7). The mower begins its chores automatically and then navigates back to its docking station when it needs recharging. "Designed for domestic lawns and gardens, it can handle any mowing task that a traditional gas or electric mower can handle, irrespective of the shape and slopes of the garden, obstacles, and type of lawn," says Dunigan. It features a three blade, 53 cm (21 inch) powerful cutting system (see Figure 8). It is kept within a specific lawn area by using buried and electromagnetic field-emitting "Perimeter Switch" wires as an invisible fence, much like dog fences. When the RoboMower returns to the docking station, the perimeter switch turns itself off.

"RoboMower is a dedicated mulching mower that mulches better than a traditional mower thanks to its Triple-Chamber-Mulching system and the 5800-RPM blade speed — double that of a typical gas mower. Grass is cut into very small clippings that are buried in the roots of the lawn, where they decompose and act like a natural fertilizer. This results in a healthier and better looking lawn, and eliminates the need to collect and remove the clippings," according to Dunigan. Figure 9 shows the less-expensive RoboMower RL850 — a mower system that does not have the automatic task time programming, auto-return to a docking station, and the intelligent perimeter switch system.

You can obtain information for the robot vacuums and lawn mowers at either **www.irobot.com** or **www.friendlyrobotics.com**. SV

THE OWNERSHIP, MANAGEMENT, AND CIRCULATION STATEMENT OF SERVO MAGAZINE, Publication Number: 1546-0592 is published monthly. Subscription price is $24.95. 7. The complete mailing address of known office of Publication is T&L Publications, Inc., 430 Princeland Ct., Corona,Riverside County, CA 92879-1300. Contact Person: Tracy Kerley. Telephone: (951) 371-8497. 8. Complete Mailing address of Headquarters or General Business Office of Publisher is T&L Publications, Inc., 430 Princeland Ct, Corona, CA 92879. 9. The names and addresses of the Publisher, and Associate Publisher are: Publisher, Larry Lemieux, 430 Princeland Ct., Corona, CA. 92879; Associate Publisher, Robin Lemieux, 430 Princeland Ct., Corona, CA 92879. 10. The names and addresses of stockholders holding one percent or more of the total amount of stock are: Jack Lemieux, 430 Princeland Ct., Corona, CA 92879; Larry Lemieux, 430 Princeland Ct., Corona, CA 92879; Audrey Lemieux, 430 Princeland Ct., Corona, CA 92879; Robin Lemieux, 430 Princeland Ct, Corona, CA 92879. 11. Known Bondholders, Morgagees, and other security holders: None. 12. Tax Status: Has not changed during preceding 12 months. 13. Publication Title: SERVO Magazine 14. Issue Date for Circulation Data: October 2005-September 2006. 15. The average number of copies of each issue during the proceeding twelve months is: A) Total number of copies printed (net press run); 12,472 B) Paid/Requested Circulation (1) Mailed Outside County subscriptions: 6,336 (2) Mailed In-County subscriptions: 0 (3) Paid Distribution Outside the Mail including Sales through dealers and carriers, street vendor, and counter sales and other paid distribution outside USPS: 1,811 (4) Paid Distribution by other classes of mail through the USPS: 0; C) Total Paid Distribution: 8,147; D) Free or Nominal Rate Distribution by mail and outside the mail (1) Free or Nominal Rate Outside-County Copies: 106 (2) Free or Nominal Rate In-County Copies: 0 (3) Free or Nominal Rate Copies Mailed at other classes through the USPS: 0 (4) Free or Nominal Rate Distribution Outside the mail: 1,180; E) Total Free or Nominal Rate Distribution: 1,286; F) Total Distribution: 9,433; G) Copies not distributed: 3,039; H) Total: 12,472; Percent paid circulation: 86.37%. Actual number of copies of the single issue published nearest the filing date is September 2006; A) Total number of copies printed (net press run) 13,377; B) Paid/Requested Circulation (1) Mailed Outside County subscriptions: 6,329 (2) Mailed In-County subscriptions: 0 (3) Paid Distribution Outside the Mail including Sales through dealers and carriers, street vendor, and counter sales and other paid distribution outside USPS: 1,842 (4) Paid Distribution by other classes of mail through the USPS: 0; C) Total Paid Distribution: 8,171; D) Free or Nominal Rate Distribution by mail and outside the mail (1) Free or Nominal Rate Outside-County Copies: 128 (2) Free or Nominal Rate In-County Copies: 0 (3) Free or Nominal Rate Copies Mailed at other classes through the USPS: 0 (4) Free or Nominal Rate Distribution Outside the mail: 1,700; E) Total Free or Nominal Rate Distribution: 1,828; F) Total Distribution: 9,999; G) Copies not distributed: 3,378; H) Total: 13,377; Percent paid circulation: 81.72%. I certify that these statements are correct and complete. Larry Lemieux, Publisher - 9/27/06.

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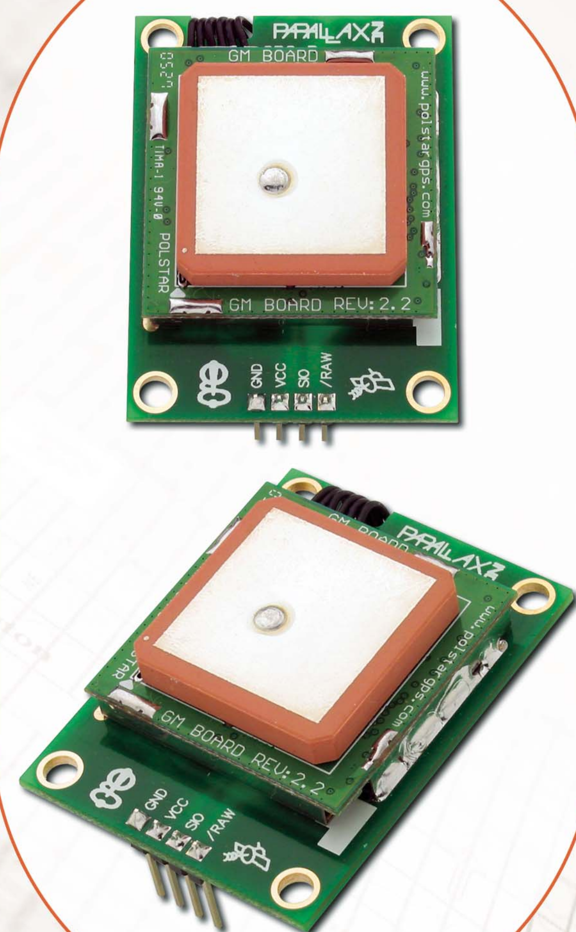

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